Noise Book

ROORKEE TREATISE ON CIVIL ENGINEERING.

SECTION VII.

ROADS

FIRST EDITION.

TO REPLACE THE SEVENTH EDITION (REVISED).

BY

Mr. W. P. HOUSDEN,

Superintending Engineer, United Provinces, Public Works Department, Buildings and Roads Branch.

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PREFACE.

THIS is a Manual for students and young engineers and not a treatise for experts. Written for the use of students at the Thomason Civil Engineering College, Roorkee, India, by one who was trained at that college and afterwards served in the United Provinces; it deals chiefly with the roads of Upper India, but the later chapters introduce the senior student to the roads of other countries. The writer has read with interest the books and papers mentioned below and gratefully acknowledges the help he has received from them.

W. P. HOUSDEN.

Dated the 21st May, 1918.

The making of highroads, ...	A. E. CAREY.
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Roads: their construction and maintenance, ...	A. GREENWELL AND J.V. ELSDEN.
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CONTENTS.

SECTION VIII—Roads.

CHAPTER I.

INTRODUCTORY GENERAL PRINCIPLES.

CHAPTER II.

CONTOURS AND GRADIENTS.

CHAPTER III.

CURVES AND CULVERTS.

CHAPTER IV.

Section of a metalled road in the plains.

CHAPTER V.

Survey design and estimate of a metalled road in flat country.

CHAPTER VI.

Hill roads.

CHAPTER VII.

Kankar collection and consolidation.

CHAPTER VIII.

Stone collection and consolidation.

CHAPTER IX.

Road maintenance.

CHAPTER X.

ARBORICULTURE.

CHAPTER XI.

EARTH ROADS—TEMPORARY ROADS—BRIDLE-ROADS.

CHAPTER XII.

DUST-PREVENTION AND MODERN ROADS.

CHAPTER XIII.

Streets, Carriageways, Gutters, Sidewalks.

CHAPTER XIV.

Diameter and Width of Wheels.

CHAPTER I.

Introductory general principles.

1. Roads are made in order to facilitate the carriage of passengers and goods from place to place with the least expenditure of motive power consistent with economy of construction and maintenance.

2. The first idea of a road is a path, or track, on which a foot-passenger can travel. In forests trees are perhaps "blazed," or marked, to show the direction; on the prairies men travel by compass, or by the stars, or by watching their own shadows. Successive travellers following the same route will tread down a path, which is the first step towards road-making. On such a road rivers would be crossed by swimming, or wading, or by means of rafts, or of felled trees used as bridges over narrow streams, while ranges of hills would be passed by following the beds of streams as far as possible.

3. As intercourse increases various animals are used as beasts of burden. Pack horses were employed in England down to a very late period; camels, horses, mules, asses and bullocks are used all over the East, while even sheep and goats carry tea and salt over the passes from India to Thibet. The employment of any of these animals necessitates the improvement of the roads, the footpaths are widened, the jungle is cleared, rude bridges are made.

4. But animal power is always more economically employed in draught than in carriage, so carts are built for conveying goods and passengers, better gradients become necessary, the road must be raised clear of inundation, better bridges must be provided, and eventually the road surface must be metalled to diminish friction.

5. With each step of improvement it is found that the traffic can pass easily over some gradients, or longitudinal slopes, on the road, but is checked by others. Over a rough country the tracks made by the inhabitants for themselves and their cattle are as direct as possible, but they are compelled to deviate from the straight line where the footpath, or cattle track, reaches ground which slopes at an angle steeper than men or cattle can climb. So also the road engineer is compelled to deviate from a direct route in order to admit on the road only such gradients as the traffic can traverse with ease. The steepest gradient considered advisable would be the maximum, or limiting, or ruling gradient for the road, and in order to avoid steeper grades, it would be necessary for engineer to cut through obstacles or to go round them.

6. The first consideration in laying out a road connecting two points is that they should be joined up by the shortest route, but a road that is straight in plan is not always the best and easiest and cheapest, for a straight road may need steep gradients, or deep cuttings where there are hills, or high banks where valleys have to be traversed. It is generally better to go round a hill than straight over it, for in this way easier grades can be secured without, of necessity, lengthening the road, since a road round a hill is not always longer than a surface road over it ; but cases may arise in which it would be better to improve the gradients on a straight road by excavation, than to make a long detour as the engineer has to avoid too lengthy a road as well as to avoid over-exertion of animal power.

7. It is also inadvisable to carry a road into low-lying land where high banks are necessary, if by a moderate deviation it can be run on to ground where good grades can be secured ; but, on the other hand, it may be advisable in some cases to adopt the straight embanked line. Circumstances will decide each case.

8. Easy gradients, as stated above, are more important on a road than a badly-graded direct route, a fact which must always be borne in mind ; but, at the same time, excessive length must be avoided, for, if there is any unnecessary increase in the length of the road, time will be wasted in travelling over it, and there will be unnecessary expenditure on its construction and maintenance. For the purpose of avoiding a steep slope it is allowable to increase the length of a road surfaced with broken stone by as much as, or more than, fifteen or twenty times the vertical height avoided by the detour, but no arbitrary rule or formula can be laid down for cases such as this, since the advisable increase depends not only on the road surface, but on the nature of the country and on the time which would be taken in travelling over the detour. *See* paragraphs 55 to 58.

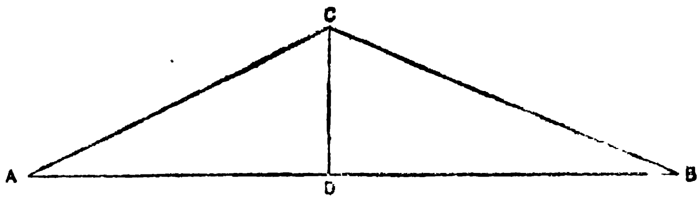
9. Small deviations do not add much to the length of a road. A deviation to the right or left of a straight line equal to 10 per cent. of the length of the line will increase the length by 2 per cent. only. This allows for some latitude in design and for the inclusion, in the scheme of a road, of towns and villages of any importance which are not far from the line. Where such towns and villages are included in the scheme, the road would ordinarily pass through any that had good wide streets, and would skirt those of which the streets were narrow, or crooked, and therefore expensive to widen and improve.

10. Whether towns and villages situated at some distance to the right or left of the direct line should be included depends on commercial considerations as well as on the physical character of the country.

In a new country the situation of towns is often determined by the position of the pioneer roads, but in an old country the alignment of a new road may depend on the positions of towns, or on land values, as well as on the natural features of the country.

11. Suppose that in a country in which the natural features do not determine the alignment of a road it is desired to make a road from A to B,

Fig. 1.



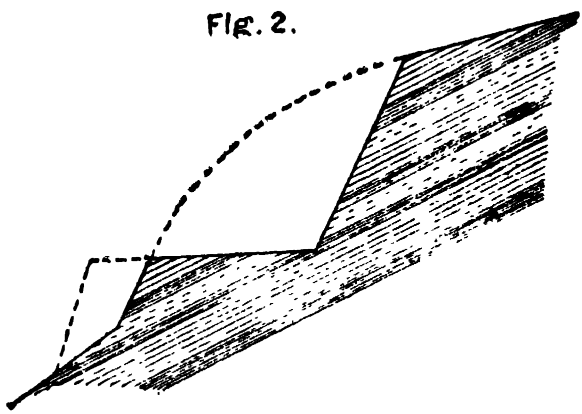
and that there is, on one side of the line, a town C which it is advisable to include in the scheme on account of its importance; the junction of the three towns may be effected in three ways. In the first place three roads AB, AC, CB may be made. These would reduce the distances between A and B, A and C, B and C to the least possible length, but the expense would be great and the aggregate length of the roads would be greater than if, from a point D on the road AB, a branch road were made to C in a direction perpendicular to AB. By this second method the length of the roads would be decreased and only a slight increase would be occasioned in the distance between C and the other two towns. The third way would be to join AC and BC, and, as a rule, it may be taken that this method is the best and most convenient for the public, that is to say, that, if the physical character of the country does not determine the course of the road, it will generally be found best not to adopt a perfectly straight line, but to vary the line, so as to serve the principal towns near its general course.

12. In laying out a line of road there are three cases which may have to be treated. First, two places to be connected may both be situated in a valley and upon the same side of it, that is, they are not separated from each other by the main stream which drains the valley. This is the simplest case. Secondly, though both are in the same valley, the two places may be on the opposite sides of the valley, being separated by the main river. Thirdly, they may be situated in different valleys, separated be an intervening ridge of ground more or less elevated. In laying out an extensive line of road, it frequently happens that all these cases have to be dealt with, and each will have to be treated on its merits, for the numerous and diverse circumstances met with in the construction of roads are such that no definite rules can be laid down to embrace all cases.

13. In European and American practice a minimum gradient is recommended, that is, roads should not be quite level, for slight gradients keep a better road surface than a dead level, as they drain better. *See* paragraphs 32 and 33.

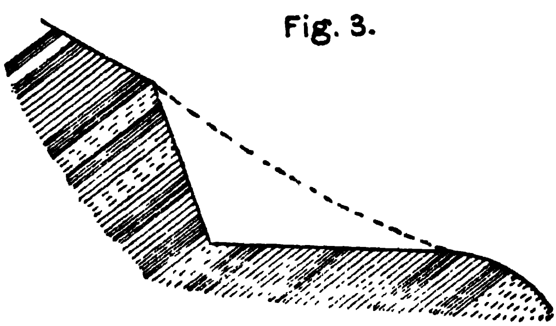
14. The question of the extent to which gradients can be reduced by curves and cuttings is often decided by the geological structure of the country. In some cases the whole alignment depends on geological considerations, or on the question of water-supply along the route, and the engineer, in prospecting for his line, should pay particular regard to these matters. He will find that there is often a great difference in the character of the ground on opposite sides of spurs and valleys, for while one side may be bare and rocky, the other may be covered with soil and forest, and have easy slopes and a good water-supply. The forests will yield timber that is useful in many ways on road works. The trees and bushes will give shade and make the road picturesque, while breaking the force of the rainfall. Nevertheless it may sometimes be better to carry the road along a bare rocky hillside as in places where snow lies long on the ground, or where the sheltered side of the spur or valley is liable to landslips. The stratification will often determine the alignment, for,

FIG. 2.



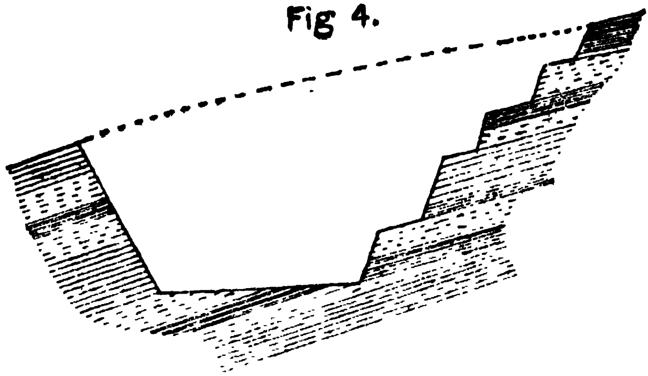
Section which is liable to slip.

Fig. 3.



Section which is likely to be safe unless there is a fault in the strata.

Fig 4.

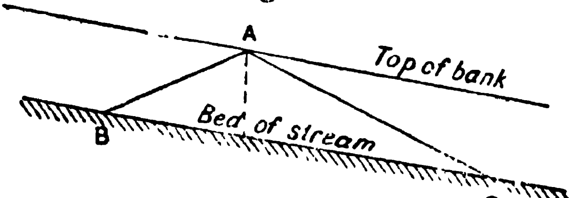


Section which requires benching back on one side.

where the strata are inclined, a road on the side of the hill towards which they dip would be liable to slip, while a road on the other face of the hill would probably be safe. In such cases a good deal would depend on the angle of inclination of the strata and the angle of repose of the soil.

15. Where a road A crosses a stream by a causeway there is a choice of two alignments for the approaches as AB, AC, and if B gives as good a crossing as C, the site B should be chosen for the causeway, as AB is shorter than AC though on the same grade.

Fig 5.



16. Roads should be made as wide as is consistent with traffic needs, for wide roads wear better and dry easier than narrow ones. They should also, as far as possible, be raised above the level of floods.

17. Consideration will show that the choice of a road alignment, while depending on principles more or less easily stated, requires judgment and the exercise of much common sense. Especially are care and skill and judgment necessary when the construction of a hill road is being considered. In level country there are not, as a rule, many alternative routes between two points, but in hilly country there may be several. One line may give good gradients, but may prove to be too long, another may be more direct, but may have to descend after a long ascent. A road may rise 1,200 feet between two points A and B, and also rise 400 feet in going from B to A, though A is 800 feet lower than B. The problem is to eliminate this superfluous rise and yet to secure as direct a route

as possible without great cost. The following case is sometimes quoted as showing what improvement can be made in laying out a road :—

"An old road in Anglesea rose and fell between its extremities, 24 miles apart, a total perpendicular amount of 3,540 feet ; while a new road laid out by Telford between the same points rose and fell only 2,257 feet ; so that 1,283 feet of vertical height is now done away with, which every horse passing over the road had previously been obliged to ascend and descend with its load. The new road is, besides, more than two miles shorter. Such is one of the results of the labours of a skilful road-maker."

18. The following example of how the comparative cost of construction may be approached in the simple case of short lengths of road in the plains of India will prove of interest. It is taken from Chapter II. of the 7th edition of the College Manual on Roads :—

"The following memoranda, by an experienced Road Engineer, on this important subject, though necessarily applying to a certain class of roads, *i.e.*, those in the plains, are a good example of the way the subject should be looked at :—

The average section of our Imperial roads in Upper India may be taken at as follow:—

Breadth of top of embankment, 40 feet.

Height of embankment, 4 feet.

Slopes, 5 horizontal to 1 vertical.

Breadth of arches of bridges, 30 feet.

Breadth of metal, 16 feet by 9 inches thick.

Rate of earthwork, Rs. 2-8 per 1,000 cubic feet.

Rate of consolidated metal per inch depth per mile, Rs. 750.

Cost of maintenance per mile yearly, Rs. 750.

Cost of drain bridges per running foot of waterway, from Rs. 75 to Rs. 100 up to 15 feet span.

Cost of large bridges, from Rs. 300 to Rs. 400 per foot.

From the above data we obtain the following comparative cost of embankments, bridges and metal for this class of road :—

Cost of one mile of embankment $(40 \times 20) \times 4 = 240$ @ Rs. 2-8 per $1,000 = 0{\cdot}60$, or Re. 0-9-7 per foot.

$\therefore$ One mile cost $5,280 \times 0{\cdot}60 =$ Rs. 3,168.

The cost of drain bridges is $\frac{75+100}{2}$ = Rs. 87-8 per foot, and of large bridges Rs. 350 per foot run of waterway.

Therefore the cost of one mile of embankment equals only 36 feet of waterway for drain bridges, and less than 10 running feet of waterway of large bridges.

One mile of metal costs $750 \times 9 =$ Rs. 6,750, or more than double the embankment; and taking the maintenance of road at Rs. 700 a year for metal and Rs. 50 for earthwork, at 20 years' purchase, we have metal $700 \times 20 =$ Rs. 14,000 a mile : therefore the cost of metal is Rs. 20,750 a mile or more than six times the cost of the embankment, and it is evident that all cross-drainage should be avoided where practicable, and that *the height of*

embankments should not be so much taken into consideration as the length of road, so as to save metal.

Secondly, as the cost of metal is such an important item, and as this so much depends on the distance from the quarries in selecting a new line, *the proximity to material for metalling should form a very great reason for adopting one line in preference to another.*

Supposing the wear and tear of metal to be 7,500 cubic feet a year per mile, and that 8 annas per 100 cubic feet are saved for each mile the road is nearer the quarries, the actual saving per annum would be Rs. 37-8 a mile, which at 20 years' purchase equal Rs. 750. Thus, if 4 miles could be saved in carriage, it would equal the first cost of the embankment nearly ; or the road may be lengthened one-sixth between two points without adding to its cost, that is, it might be 16·66 per cent. longer, which would admit of a diversion of about one-third of the total distance out of the straight line.

Lastly, where nothing is to be gained by deviating from the straight line, either in avoiding drainage or being nearer kankar beds, the embankment may be raised as follows, without adding to the cost of the road, *i.e.*, with the following rates for earthwork :—

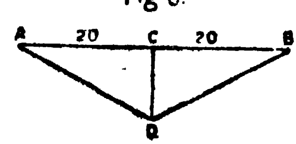
Height of embankment up to 5 feet, Rs. 2-8 per 1,000.
„ „ above 5 and up to 10, Rs. 3 per 1,000.
„ „ 10 and up to 15, Rs. 3-8 per 1,000.

Saving in distance	1 mile	in 2.	or ½,	embankment	may be raised	to 13·00	feet.
	1 „	„ 3	„ ⅓	„	„	10·00	„
	1 „	„ 4	„ ¼	„	„	8·40	„
	1 „	„ 5	„ ⅕	„	„	7·45	„
	1 „	„ 6	„ ⅙	„	„	6·64	„
	1 „	„ 7	„ ⅐	„	„	6·10	„
	1 „	„ 8	„ ⅛	„	„	5·80	„
	1 „	„ 9	„ ⅑	„	„	5·50	„
	1 „	„ 10	„ ⅒	„	„	5·33	„
	1 „	„ 15	„ 1/15	„	„	5·00	„

That is, if the road can be shortened 1-20th to 1-15th of its length, it will allow of an addition of one foot to height on an average throughout the whole length of embankment ; from 1-15th to 19th, we may add 1½ feet ; from 1-9th to 1-7th, 2 feet ; for 1-6th and 1-5th, 3 feet ; if ¼ is gained, 4½ feet ; where ⅓, 6 feet : and where the distance is halved, we may add no less than 9 feet to the height of embankment. That is supposing a valley to intervene, which is one mile broad, and requires an embankment averaging 13 feet high to cross it, and that by going a circuitous road we should avoid this bad ground, but add one mile to the length of the road (all other circumstances remaining the same along the line) it is as *cheap* to make the 13 feet embankment as to go the same circuitous route, while travellers are saved one mile. In other words, it is very seldom a road should be made to deviate from the straight line on account of earthwork only, except in a hilly country where steep gradients would interfere.

Considerable deviations can, however, be made from the straight line without adding much to the actual length of road, as will be seen by the following :—Let A and B be (say) 40 miles apart, and half way, at the point C, lay off the perpendicular line CD. Suppose CD is one-tenth of AB, the line ADB will only exceed AB 2 per cent. The Engineer, therefore, at half the distance between the two points to be connected, has a breadth of 8 miles to select from, without adding more than 2 per cent. to the whole length of road.

Fig 6.



As long as the direction of no part of the line deviates more than 10° either way, from the direction of the straight line joining the terminal points of the road, then, for all practical purposes, the road will be nearly as short as the direct line, while it gives the engineer considerable scope for selecting his line. In doing which he should consider, *first*, the Drainage; *secondly*, the supply of metal; and *lastly*, the Earthwork, which though at first sight it appears the greatest, is in reality insignificant in comparison to the other two items.

A straight line is undoubtedly the shortest distance between two points, but nothing is more monotonous than to have to march along a straight road. In fact, one should never be able to see more than three miles along any road; and this can be easily accomplished by passing round a village or a clump of trees. Curves, however, are unsightly in an open plain, unless there be some natural feature in the country necessitating a curve, such as to cross a stream at right angles, or to avoid low marshy ground, or some high mound. In the latter case the mound can be taken advantage of in hiding the road. Where, however, all is one extensive plain, as one often meets with in India, to put a curve in a road and not to *hide* it appears as if a mistake had been made in lining it out, which is worse than a continuous long line.

Curves may, however, be given at every three miles, so that no portion of the road can be seen for a greater distance, and the road greatly improved, not only in appearance,

Fig. 7.

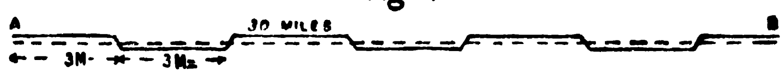
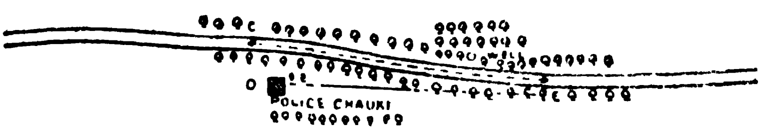


Fig. 8.



but also in comfort to travellers. Suppose the distance between the two points it is necessary to connect is 30 miles, and that the country is one open uniform plain. The shortest line would, no doubt, be one uniform straight, but it would be too tedious and would involve long marches of 15 miles each, with nothing to break the monotony of the march. By introducing double or S curves at every three miles, and planting two clumps of trees near them on either side of the road, with a well in the centre of one of them, the road could only be seen along three miles of its length, and wearied travellers would have comfortable shade with water to drink. A Police Chauki could be placed in the other clump, as to afford protection to property.

Supposing DE to be equal to 1,000 feet, and CD equal 50 feet, than $\sqrt{1{,}000^2 + 50^2} = 1001{\cdot}24$ feet, or nine of these curves may be introduced, and only add to the length of the road in a distance of 30 miles, some four yards."

19. The rates given in this example do not apply to any particular part of India. Those for kankar are higher than are prevalent in the United Provinces where also banks are made 30 feet wide, with side slopes of 2 to 1, and are not often of an average height of 4 feet.

20. Another example is reproduced from the Manual on Roads, 7th edition, Chapter II, paragraphs 44 and 45, as follows :—

"Say that it is proposed to substitute a good metalled road in place of a kachcha road actually existing in any district, the road being already raised and bridged.

As a first step, returns of actual traffic must be made. These will be taken by observers stationed at different points with printed forms in their hands, showing the number and description of carriages, carts and animals, whether laden or unladen, passing to and fro. They should be taken for several successive days, care being taken to ascertain whether it is average traffic or due to any special and temporary cause, such as the holding of a fair of the like.

The cost of this traffic is next to be considered. Let us neglect the question of speed and consider only the weight. Assume that the road is 30 miles long, and that 500,000 maunds (of passengers, cattle, grain, etc., a very moderate amount) are annually carried. The average friction of a kachcha road may be taken at $\frac{1}{20}$th of the weight. The annual force of draught required will, therefore, be 25,000 maunds = 2,000,000 lbs. If the average power of draught of a bullock at 1·5 miles an hour for 10 hours a day be taken at 50 lbs., there would be required 80,000 bullocks to transport the above in one day. And taking the daily hire of a bullock at 4 annas, the annual cost of transport of the above traffic would be Rs. 20,000.

Let the road now be supposed to be metalleds—so that the animals would draw three times as much as before.

Then the saving would evidently be Rs. 13,333 per annum, which the carriers could afford to pay either in tools or in paying for the metalling themselves. If the money were borrowed at 10 per cent., this would represent a capital of $1\frac{1}{3}$ lakhs, and as the cost of the metalling would not exceed Rs. 90,000 at Rs. 3,000 a mile, there would be a clear gain of Rs. 40,000 or 30 per cent., besides the saving in time, and in wear and tear of animals and vehicles, and the profit on extra traffic, which would be attracted to the good road, which might be set against the annual cost of repairs.

Next, suppose the old road is only to be improved by being shortened a mile by a new alignment of part of it. Then $\frac{1}{30}$th of the original distance, and therefore labour = Rs. 667, would be saved, representing a capital of Rs. 6,670, and if the proposed diversion can be made for this sum, it should be made at once. It is clear there will be a further saving in having a mile of road less to repair.

2

Next, suppose that the original road has a heavy gradient, 1 mile long at a slope of 10 to 1 to the top of a hill, which it descends by a similar gradient on the other side; and that by making a detour of a mile the gradient can be reduced to 30 to 1. It is generally allowed than an animal can draw $2\frac{1}{2}$ times as much in the latter case as in the former, so that to draw the above the traffic would cost Rs. $\frac{2\cdot5 \times 20,000}{15^*}$ = Rs. 3,333 more annually than with the higher gradient; so that if the extra mile could be made for Rs. 30,000 it would be worth making.

These calculations will show the principles on which similar ones in like cases should be conducted. Some such calculations should, whenever practicable, accompany every design for a new road. It is true, as remarked above, that the pecuniary return would be nominal, rather than real, so far as the Government was concerned, but it would at least serve to show the absolute benefit to the community that would arise from constructing or improving the road; and indirectly no doubt a good road is as profitable to Government as a good canal."

21. As an exercise the student should make the calculations on the assumption that the average friction of an earth road is one-tenth of the load to be drawn.

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* One-fifteenth of the whole distance.

CHAPTER II.

CONTOURS AND GRADIENTS.

22. A good map is of great help in the choice of the preliminary line of a road, and if the map is a contoured one, a good deal of work in the field will be saved. Contours are lines of equal altitude and represent imaginary lines running round a hill, or a valley, or a lake, at the same level all the way at certain heights above a known fixed point termed the datum, these heights being indicated by the figures written on the lines. The vertical intervals between consecutive contours are equal. The horizontal distance apart of the lines representing them depends on the slope of the ground. When the lines are far apart the slopes they represent are easy; when they are close together they represent steep slopes.

23. Imagine a lake that is gradually filling with water and suppose that an outline plan of the wetted perimeter is drawn whenever the water surface rises five feet. The completed drawing, Fig. 9, would show contours at 5 feet vertical intervals and contours pointing away from the centre, *i.e.*, salients, would indicate drainage lines. Imagine now a hill, Fig. 10, from which flood waters are receding. As the flood falls 5 feet contour lines are drawn, as in the case of the lake, and the completed plan again indicates contours at 5 feet vertical intervals, but in this case contours pointing away from the centre of the plan, *i.e.*, salients, indicate spurs, while drainage lines are indicated by contours that bend in towards the centre of the plan, *i.e.*, re-entrants.

Fig. 9.

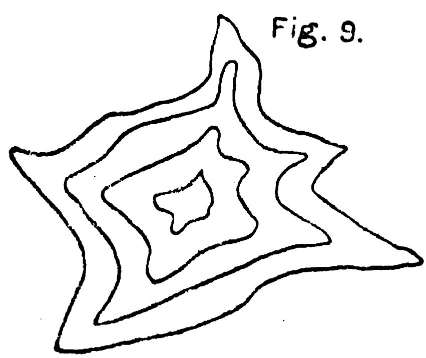
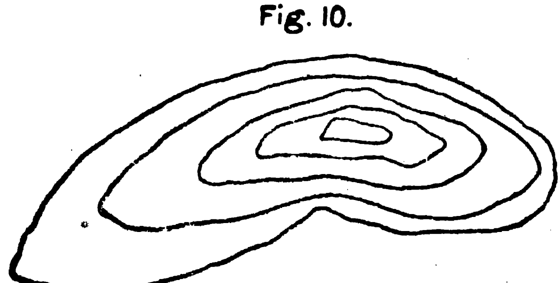


Fig. 10.



24. Contour lines, by their greater or smaller distance apart on a drawing, have the effect of shading and show at a glance ridges, spurs, drainage lines, steep slopes, easy slopes. The heights of points on the drawing can be calculated by counting the number of contour lines from any convenient level when the contour heights are not all marked in figures on the plan. The difference in level between two places is found by multiplying the number of intervening contours by the vertical height between contours.

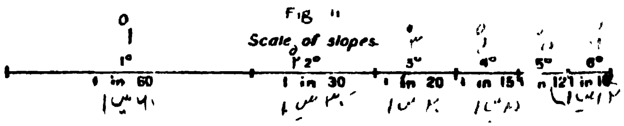
25. A rough trace of a road at any gradient can be marked out rapidly on a contoured plan. For instance, if the contours are at 5 feet intervals and the gradient is 1 in 30 or 5 in 150, it is necessary only to separate the points of a divider to a distance apart representing 150 feet on the scale of the drawing, to place one point of the dividers on a contour line, and the other on an adjacent contour line, and a trace of 1 in 30 is at once indicated. If it is necessary to ease the grade, this can be done by scaling off more than 150 feet on the dividers.

26. A small contoured plan for use in the design of bridge approaches, or protective embankments, can very easily be prepared if a number of levels are taken and plotted on a plan. When this is done it is a simple matter to connect up points of equal altitude. For large plans, where a very large number of levels is required, such an instrument as a tacheometer needs to be used, to save time and labour in making the survey.

27. Models of hills and valleys can be made from a contoured plan. To make a model it is necessary to take a tracing of each contour, to place each tracing separately on wood of a given thickness, say quarter inch wood, and to cut with a fretsaw along the contour lines. The resulting wooden shapes when placed on each other in their correct positions and order will form a stepped model of the country represented by the map. When the stepped edges have been sloped off by means of woodcarving tools and the surface has been painted, the model will be ready.

28. In dealing with contoured maps it is necessary to understand the use of a scale of slopes. Gradients may be expressed by the difference in level which occurs in a certain horizontal length compared with that horizontal length as, for example, 1 in 20 or 5 per cent., or the slope may be expressed in degrees of elevation above a horizontal plane. A slope of one degree represents a rise of one foot vertically in a horizontal distance of 57·3 feet and so for 2°, 3°, 4°, 5°, 6° the distances are 28·6, 19·1, 14·3, 11·4, 9·5 feet, respectively. If these distances are marked out on the same scale as the contoured plan,

they will represent a scale of slopes by which the angles of the slopes of the hills, etc., shown on the plan can be measured.



For all practical purposes of rough calculation—

1°	is equivalent to a slope of	1 in 60
2°	,,	1 in 30
3°	,,	1 in 20
4°	,,	1 in 15
5°	,,	1 in 12
6°	,,	1 in 10

29. From a contoured plan a longitudinal section can readily be drawn along any given line on the plan by noting where the given line cuts the contour lines and setting up ordinates at these points on which the heights of the points can be marked, and connected by lines which will represent the surface of the ground.

30. The gradient of a road is its longitudinal slope, which may be expressed in degrees of elevation above a horizontal plane or as a proportion between the ascent or fall in a certain horizontal length and the horizontal length, *i.e.*, the tangent of the angle of elevation, as 1 in 20, which may also be called 20 to 1 or a 5 per cent. grade. A grade of 1° is equivalent to a grade of 1 in 57·3, a grade of 2° is equivalent to a grade of 1 in 28·6, and so on, as explained above in paragraph 28. Sometimes grades are measured by the rise or fall in a certain length, measured along the road surface, as compared with this length, *i.e.*, as the sine of the angle of elevation which, for grades up to 6° (which corresponds very nearly to 1 in 10) is about the same as the tangent of the same angle.

31. The grades allowed on a road vary from the minimum grade to the maximum. Between these would lie the average grade which, in the case of a constantly ascending or descending road, is the total rise or fall divided by the total distance. The minimum gradient is the least that can be allowed consistent with good drainage. The maximum advisable gradient is the steepest grade that animals drawing a load can traverse for short distances by exerting about double the energy that is needed to move the same load on the level. This is also called the ruling gradient, or the limiting gradient

32. In European and American practice it is accepted that roads should not be quite level, and they are made as far as possible with a minimum longitudinal slope for purposes of good drainage. This slope is fixed by one authority at 1 in 80, by another 1 in 115, and in France at 1 in 125. While it is easy to secure a minimum gradient in undulating country, or in country that has a natural uniform slope, in the direction of the road, greater than the fixed minimum gradient, cases must arise where the slope of the country in the direction of the road is less than the grade of 1 in 125 indicated above, and it would be necessary, in such cases, in order to secure a minimum gradient of 1 in 125, to make a series of alternate slopes or reverse gradients. In these cases the minimum slope cannot well be worked to.

33. The adoption of a minimum grade in a flat country such as the plains of India is not always practicable, but, at the same time, long stretches of flat road should be avoided, especially in cuttings, for, while an approximately level road does not seriously affect traction, an accurately level road is either not properly drained or has, in towns, gutters and side drains which require to be made to slope to inconvenient depths below ground. Slight gradients maintain a better road surface than does a dead level, a result which is generally to be attributed to the better drainage on the incline; and it is said that on level roads the consumption of materials for repairs, compared with that of a similar length of road on a slight incline, and subjected to the same amount of traffic, is some 15 to 25 per cent. greater in the former case than in the latter. The cross-slope of a road, from the centre to the edge, is intended to assist drainage, but as the road surface tends to wear into longitudinal ruts or tracks which interfere with this drainage, water lies on the road surface, where it is on a dead level longitudinally, and damage results. Whether alternate slopes of slight gradient are less fatiguing to horses than a dead level is a matter on which authorities are divided, but it is accepted that an approximately level road does not affect traction appreciably and drains better and costs less to maintain than truly level roads.

34. Steep gradients, on the other hand, affect traction greatly and the question of maximum gradients is of great importance. This question is closely connected with the character of the road, its alignment, and the sort of traffic that preponderates in the particular district under consideration.

35. Although a ruling gradient may be laid down in an engineer's instructions for a road in a flat country, he may be able to choose a cheap and short line and yet may not be obliged to adopt gradients

nearly as steep as the ruling gradient, except in special places such, for example, as some bridge approaches. In the case of a mountain road the ruling gradient needs more consideration, because the road is likely to be made as near the ruling grade as possible. The engineer may be instructed not to give more than a stated proportion of the length of his road, or more than a certain continuous length, a gradient as steep as the ruling gradient; but if he is not thus restricted he will adopt the ruling gradient, as far as possible, because the steepest grade admissible is likely to give the shortest and cheapest route.

36. The theoretical maximum gradient for any given surface is fixed chiefly by two considerations: one relating to the power expended in ascending, the other to the acceleration in descending the incline, both of which depend on the nature of the road surface; but, in practice, questions of cost of construction and of the time taken in travelling over the road have to be thought of. In the case of mechanically propelled vehicles it is possible to calculate approximately the influence of slopes, and speeds, and surfaces, on tractive power; but in the case of animal draught the hours of work, and the fact that a horse loses power on slopes out of proportion to the mathematical loss of power, alter the problem. All tables given below must, therefore, be treated as approximations. The figures, while of little value as an absolute measure of what may be done in any particular case, are of use as a rough comparison of the relative tractive properties for animal draught, of different surfaces and grades.

37. Authorities differ as to what should be taken as the tractive power of a horse, and this is not to be wondered at when the varying designs of vehicles, and the varying diameters of their wheels, and the strength and speed of individual horses are taken into consideration along with their adaptability or training for any particular class of work. For the purposes of the calculations given below, it will be held that a horse trotting on an ordinary macadamized road in good order draws a load of about 1 ton. It will also be held that the resistance to traction on the level is one-thirtieth of the load, or say 75 lbs., taking the load at 2,250 lbs.

38. Some notes on resistance to traction are given here. For others, *e.g.*, the conclusions of Morin, Dupuit, etc., Chapter XIV. should be referred to.

39. Resistance to traction of a vehicle consists of I.—Wind resistance, II.—Axle friction, III.—Rolling resistance, IV.—Grade resistance.

I.—Wind resistance is variable. Its average results must be considered as included in the result of experiments on rolling resistance. A

light breeze at 15 miles an hour represents 1·11 lb. per superficial foot normal to its direction, while at a velocity of 50 miles an hour the force is equal to 12·30 lbs. per square foot of the surface exposed to it.

II. Axle friction has nothing to do with the ordinary surface of a road and is less in a properly-designed vehicle than in a rudely-built conveyance.

III.—The resistance of a wheel to rolling is due to the yielding, or indentation, of the road which causes the wheel constantly to be climbing an inclination. It varies with—

(*a*) The diameter of the wheel. Morin says inversely as the diameter. Dupuit says inversely as the square root of the diameter. Clark says inversely as the cube root of the diameter. Baker says inversely as the square root of the mean diameter.

(*b*) The width of the tyre. If the wheel tends to cut into the road, the resistance to traction is increased as the tyre width decreases, otherwise the width beyond 3 or 4 inches has practically no effect on the traction.

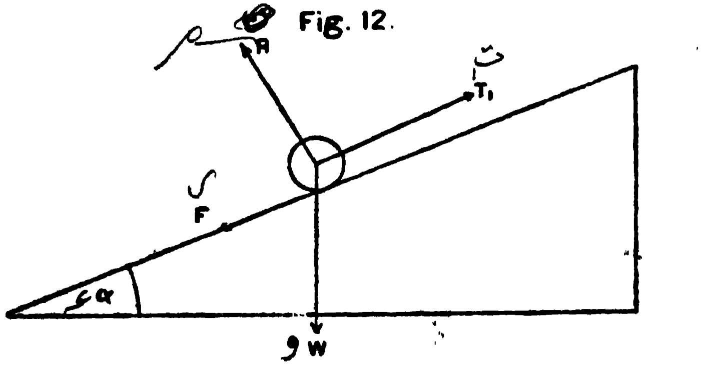
(*c*) The speed. The resistance increases to some extent with the velocity.

(*d*) The presence or absence of springs on the vehicle. Springs decrease the resistance to traction by decreasing the concussion due to irregularities of the ground and obstacles on a road.

(*e*) The nature of the road surface. The harder and smoother the surface the less the resistance.

IV.—Grade resistance is due to the force of gravity and is represented by w sin a (which is practically the same as w tan a for grades up to 1 in 10) where a is the inclination of the slope to a horizontal plane.

Fig. 12.

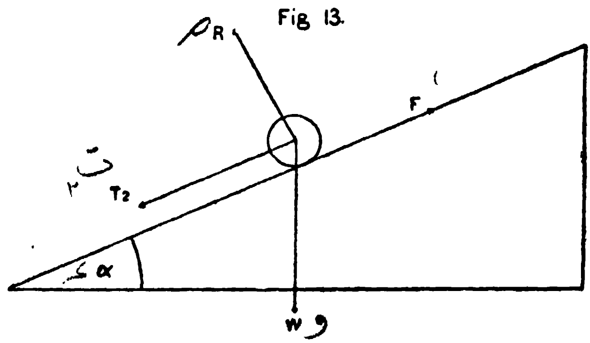


40. If a body of weight w is drawn up an inclined plane, on which the co-efficient of friction is μ, and which is inclined at an angle of a

degrees to the horizontal by a force T_1, considered in these examples as parallel to the plane, and if R is the reaction perpendicular to the plane, then the friction between the body and the plane, which is indicated by F, is equal to μR, and—

$$T_1 = W \sin a + F \text{ (along the plane)}$$
$$= W \sin a + \mu R$$
$$R = W \cos a \text{ (perpendicular to the plane)}$$
$$\therefore T_1 = W (\sin a + \mu \cos a) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Fig 13.



41. If the body is coming down the plane, and if a is less than the angle of friction ϕ, it needs a force T_2 to pull it down, and—

$$T_2 + W \sin a = F = \mu R = \mu W \cos a$$
$$\therefore T = W (\mu \cos a - \sin a) \ldots\ldots\ldots (2)$$

but if a is greater than the angle of friction the body needs to be retarded so—

$$T_3 + F = W \sin a$$
$$T_3 = W (\sin a - \mu \cos a) \ldots\ldots\ldots\ldots\ldots (3)$$

42. By (1) $T_1 = W (\sin a + \mu \cos a)$
$$= W \sin a + \mu W \cos a$$

but $\cos a$ is unity for small values of a, so—

$$T_1 = \mu W + W \sin a \ldots\ldots\ldots\ldots\ldots (4)$$

Now μW is the force that must be exerted if there is friction, but no gradient, and $W \sin a$ is the force that must be exerted if there is a gradient a, but no friction, and thus it follows that, for small values of a, the pulling force on a vehicle when it is being pulled up a slope of 1 in n is equal to the pull necessary on a level road plus $\frac{1}{n}$th of the weight of the vehicle. For small values of a, $\tan a$ and $\sin a$ are practically the same and if grade is 1 in n, for which $\tan a = \frac{1}{n}$, $\sin a$ may be taken as $\frac{1}{n}$.

If s is written for $\tan a$ or $\sin a$ or $\frac{1}{n}$

$$T = \mu W + sW = W (\mu + s) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

and from this formula it is possible to calculate the effects of gralients on self-propelled vehicles.

Suppose, for instance, that the weight is 2,250 lbs. and the co-efficient of friction is $\frac{1}{30}$, then w = 2,250 lbs. on the level, but on a slope of 1 in 20.

$$w = \frac{T_1}{\mu + s} = \frac{T_1}{\frac{1}{30} + \frac{1}{20}} = 12 T_1$$

= 900 lbs. only.

43. In the case of animal draught, apart from other matters, the weight of the animal has to be considered in calculating the loads that can be drawn on slopes, for it is not taken into consideration in estimating the amount of the load $\frac{T_1}{\mu}$ that can be drawn on level roads and the formula—

$$T_1 = \mu w + sw + sH \qquad (6)$$

should be used, H being taken to represent the weight of the horse.

A horse can easily pull with a force eqnal to one-tenth of his weight or—

$$\frac{H}{10} - sH = \mu + sw$$

$$w = \frac{\frac{H}{10} - sH}{\mu + s} \qquad (7)$$

and for short distances he can exert about double this pull (sometimes more) so that—

$$W = \frac{\frac{H}{5} - sH}{\mu + s} \qquad (8)$$

and for very brief periods of time he can pull with a force equal to half his weight, or more, as in starting a load.

44. The weights of horses and their tractive force vary considerably and the loads drawn may be considered in terms of their weight as in Table I below :—

TABLE I.

Loads drawn in terms of weight-when exertion = $\frac{H}{10}$

$W = \frac{\frac{H}{10} - sH}{\mu + s}$			$\frac{H}{10}$ = Tractive force.	
Grade S.	Co-efficient of friction μ			
	$\frac{1}{100}$	$\frac{1}{30}$	$\frac{1}{20}$	$\frac{1}{10}$
Level, ...	10·00	3·00	2·00	1·00
1 in 100, ...	4·50	2·08	1·50	·82
1 „ 40, ...	2·14	1·28	1·00	·60
1 „ 30, ...	1·54	1·00	·80	·50
1 „ 20, ...	·83	·60	·50	·33
1 „ 10. ...	...	...	...	...

This table shows how surfaces and grades affect the load that can be drawn when the draught power remains unchanged. The figures are relative. If a horse pulling

one-tenth its weight H can draw 4·50 H on a grade of 1 in 100 when $\mu = \frac{1}{100}$, it can draw only 2·08 H when $\mu = \frac{1}{30}$ on the same grade, and it can draw only 1·00 H when $\mu = \frac{1}{30}$ on a grade of 1 in 30. It cannot draw anything over a grade of 1 in 10.

45. The next table expresses the loads for the same draught in terms of the loads on the level.

TABLE II.

Loads drawn in terms of loads on the level when exertion $= \frac{H}{10}$.

$$W = \frac{\frac{H}{10} - SH}{\mu = S} \qquad \frac{H}{10} = \text{Tractive force.}$$

Grade S.	Co-efficient of friction μ $\frac{1}{100}$	$\frac{1}{30}$	$\frac{1}{20}$	$\frac{1}{10}$
Level, ...	1·00	1·00	1·00	1·00
1 in 100, ...	·45	·69	·75	·82
1 „ 40, ...	·21	·43	·50	·60
1 „ 30, ...	·15	·33	·40	·50
1 „ 20, ...	·08	·20	·25	·33
1 „ 10, ...	...	...	...	...
Approximate values of μ	Asphalt $\frac{1}{100}$	Metalled road $\frac{1}{30}$	Earth road $\frac{1}{10}$	

This table shows how, for the same load, power is lost on grades on smooth surfaces quicker than on rough surfaces, but it must be remembered that greater loads can be drawn on smooth surfaces than on rough ones.

46. The fact that a horse can exert double the ordinary pull for a short time has sometimes been used in connection with the formula—

$$T = \mu W + SW$$

to determine the maximum advisable gradient for short lengths, the reasoning adopted being that the load for the level road should be fixed so as to make μW equal to the ordinary tractive power of the horse, and, since twice this tractive power can be exerted for short distances, SW may be made equal to μW or $S = \mu$, that is the maximum gradient should not exceed the co-efficient of friction.

But this calculation omits the effect of gravity on the wieght of the horse. The maximum advisable gradient should be calculated from the formula—

$$2T_1 = \mu W + SW + SH \dots\dots\dots\dots\dots (9)$$

Taking $\mu = \frac{1}{30}$ W = 2,250 lbs. on the level, T_1 = 75 lbs. and H′ = 750 lbs., the maximum advisable gradient would, in the former case, be 1 in 30 and in the latter 1 in 40.

47. Table III below gives the load in terms of weight of the horse when the tractive pull is one-fifth of the weight, *i.e.*, twice as much as is considered in Table I, paragraph 44.

TABLE III.

Loads drawn in terms of weight H when exertion $= \frac{H}{5}$.

$$W = \frac{\frac{H}{5} - SH}{\mu + S} \qquad \frac{H}{5} = \text{Tractive force.}$$

Grade S.	Co-efficient of friction μ $\frac{1}{100}$	$\frac{1}{30}$	$\frac{1}{20}$	$\frac{1}{10}$
Level, ...	90·00	6·00	4·00	2·00
1 in 100, ...	9·50	4·38	3·17	1·73
1 „ 40, ...	5·00	3·00	2·33	1·40
1 „ 30, ...	3·85	2·50	2·00	1·25
1 „ 20, ...	2·50	1·80	1·50	1·00
1 „ 10, ...	·91	·75	·66	·50
1 „ 5, ...	Nil	Nil	Nil	Nil
Approximate values of μ, ...	Asphalt $\frac{1}{100}$ Stone road $\frac{1}{30}$ Earth $\frac{1}{10}$.			

Read with Table I., this table shows that if a horse can draw 3 times his weight on a level macadam road, he can, by doubling his exertion for a short time, draw 3 times his weight over a short length of a grade of 1 in 40, which may thus be taken as the maximum advisable gradient on a metalled road for horse-drawn traffic. If steeper grades are to be used, as they must be on hill roads, the roads must be reduced.

48. As regards the down grade, it is known that a horse can trot on a down grade of 1 in 30 on a metalled road, so 1 in 40 cannot be objected to. A gradient of 1 in 40 may, therefore, be accepted as the maximum advisable gradient for quick traffic on short lengths of a metalled road, whenever this gradient can be worked to, as in the case of a road on the plains, where, as stated above, an engineer can generally design a road with gradients which may not be nearly as steep as the maximum.

49. In the case of hill roads, however, it is not practicable to adopt even the maximum that is desirable in the interests of the traffic. A hill road of broken stone planned at 1 in 40 would be expensive and long. Roads in the hills have, therefore, to be made with steeper gradients and lighter loads have to be carried. Experience shows that 1 in 20 is too severe a grade to permit of carriages drawn by horses ascending for any distance except at a slow pace without a great expenditure of energy, so this grade should not be used for any but very short lengths even with light loads, and it is not advisable to prescribe it as a maximum

gradient. This may be 1 in 25 for a metalled road in the hills which is intended for quick traffic, with permission to use 1 in 20 for very short lengths where 1 in 25 cannot be arranged for. If the road is not to carry quick traffic, the grade may be 1 in 20 instead of 1 in 25. With a grade of 1 in 25 slow traffic could surmount a continuous ascent of 10 miles without a halt or undue exertion. Such a grade would not reduce quick traffic to a walk, and it would permit of horses descending with safety at a fair speed.

50. Whatever grade is adopted the loads should conform to it, or there will be resultant cruelty to animals, for if, as very often happens, loads are fixed with reference to performance on the level, it is expecting too much of animals to require them to haul these loads up continuous grades of 1 in 25 when double their ordinary exertion will serve only to carry the loads over short lengths of 1 in 40.

51. The remarks made above have reference to water bound metalled roads. Any smoother surface would mean easier gradients, longer roads and greater expense. Tar-sprayed metalled roads are becoming a necessity in many countries and will be referred to in a later chapter. Cobble stones, asphalt, wood blocks, stone setts are other forms of road surface, and each will have its own maximum gradient ; but these surfaces are not suitable for hill roads.

52 ~~25.~~ Just as authorities differ in matters relating to the draught of animals, so in questions of the resistance of surfaces there are differences. Experiments are made in many ways, on many kinds of surfaces, under varying conditions, and it is impossible to summarise the results so as to give a definite reply to the question :—" What is the co-efficient of friction of a given road surfacing material ? "

53. For broken stone roads early authorities adopted $\frac{1}{30}$ as the value of μ and Telford prescribed a ruling gradient of 1 in 30 for the roads he improved, admitting, however, 1 in 22 and 1 in 17 for very short lengths. The maximum grade adopted by French engineers for macadamized roads is 1 in 20. It is evident from what has been said above that no fixed maximum gradient can be adopted in all situations, and it is sometimes said that for fast and light traffic the grade on macadam should not exceed 2 per cent, for mixed traffic 3 per cent. may be adopted, while for slow wheeled traffic combined with economy 5 per cent. should not be exceeded, a grade which is practicable, but not convenient. The maximum grades recommended in this Manual for fast traffic on macadamized roads vary from 2½ per cent. for exceptional situations on roads which are otherwise provided with very easy grades to 4 per cent. on continuous lengths of hill roads, with grades of 5 per cent. in exceptional situations and for very short lengths of a few hundred feet. The

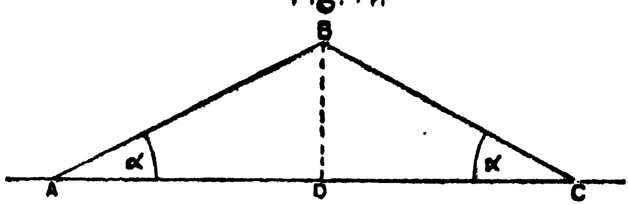
Military Works Handbook prescribes a maximum of 1 in 20 for hill roads, with 300 feet practically level in each mile and a rise of less than 240 feet per mile, but it is better to work to 1 in 25 as far as is practicable.

54. From a table of the resistance to traction on different road surfaces prepared by Rudolf Hering and published in Byrne's "Highway Construction" the following figures of the resistance in pounds per ton are extracted. It should be noted that they are not all from experiments by one authority or at the same speed, a fact that discounts their usefulness, but they will serve to give an idea of the advantages of a smooth and firm surface. Only some of the figures in the list have been extracted:—

	Resistance in pounds per ton.
Sand,	448
Sandy road,	187
Gravel (loose),	320
„ (hard rolled),	75
Earth (ordinary road),	224
„ (dry and hard),	100 to 75
Cobble stones (ordinary),	280
„ (good),	75
Macadam (old),	90
„ (good, slightly muddy),	75 to 41
„ (very hard and smooth),	45
„ (best),	52 to 30
„ (bad),	160
Granite block (ordinary),	90
„ (good),	45
Planked roadway,	56 to 40
Asphalt,	17
Iron tramway,	11

55. A question sometimes arises as to the allowable increase that may be made in a length of road if it is carried on the level in order to avoid a height or a dip.

Fig. 14.



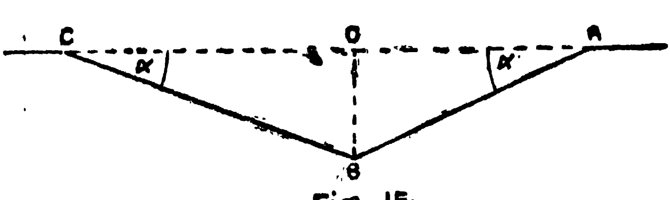


Fig. 15

If a is less than ϕ (the angle of friction)

$$T_1 \text{ up AB} = W\,(\sin a + \mu \cos a)$$
$$T_2 \text{ down BC} = W\,(\mu \cos a - \sin a).$$
$$\therefore T_1 + T_2 = 2W\,\mu \cos a$$

which for small values of a is practically the same as $2\,\mu$ W.

Therefore theory says that the length of the road should not be increased when a is less than the angle of friction for the work along ABC is about the same as along ADC.

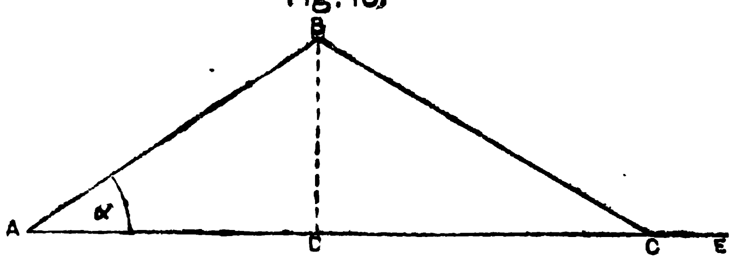
56. In dealing with maximum gradients it was said that a nearly level road does not appreciably affect traction, and this calculation shows there is no harm in short reverse grades, or alternate slops, when the inclination is less than the angle of friction. Some people go so far as to say they are better than a level road from the point of view of the horse, as a dead level fatigues a horse more than alternate slopes of slight gradients. This has not been established. Theoretically they give him no extra work to do and they certainly assist in draining the road surface.

57. When a is greater than ϕ

$$T_1 = W\,(\sin a + \mu \cos a)$$
$$T_3 = W\,(\sin a - \mu \cos a)$$
$$\therefore T_1 + T_3 = 2W \sin a$$

Therefore the theoretical work done along ABC is the same as that done in lifting the weight W through twice the height of the obstacle BD.

Fig. 16.



Now if AE is taken to represent the distance on the level on which the work done is equivalent to the work along ABC

$$AE \times \mu W = 2BD \times W$$
$$AE = \frac{2BD}{\mu} = \frac{2h}{\mu}$$

and the extra length is AE − AC (as AC practically equals AB + BC) *i.e.*,—

$$AE - 2AD = \frac{2h}{\mu} - \frac{2h}{S}$$
$$= 2h\left(\frac{1}{\mu} - \frac{1}{S}\right)$$

For a road on which $\mu = \frac{1}{30}$ and $S = \frac{1}{20}$ the extra length = 20h, so if h = 132 feet, the road may be made half a mile longer on the level.

58. This is the theoretical increase based on the power expended; but reasoning based on tractive force is not equally applicable to roads and railways, to animal draught and motors. Vital energy as expended by draught animals is one thing, mechanical force is another. A man would prefer to walk five miles up an ascent of 1 in 24 to tramping 10 miles on the level. He would be less fatigued by his exertion on the shorter journey. With draught cattle it is the same within certain limits. With steam or other power the matter is reduced to a question of cost.

CHAPTER III.

CURVES AND CULVERTS.

59. Where a road is for horse-drawn traffic, the radius of a suitable curve would depend on the over-all length of the horses and carriage and the width of the road, and in American practice it is usual to allow, in the case of a vehicle drawn by four horses on a 12-foot road, an inside radius of about 100 feet, on a 16-foot roadway 75 feet, and on an 18-foot roadway 66 feet.

60. For hill roads St. Clair Wilkins recommends a radius of 100 feet, but in difficult situations allows for a curve of 90 degrees a radius of 60 feet, for a curve of 60 degrees a radius of 70 feet, and for a curve equal to or exceeding a semi-circle a radius of 80 feet, measured in each case to the centre line of the road, which is taken as 20 feet wide.

61. In France it was usual to allow for horse-drawn traffic on main and departmental roads of which the tramway is 20 to 22 feet wide, 165 feet, and in extreme cases 100 feet; on principal country roads, which are 20 feet wide, 50 feet, measured presumably to the centre of the road in each case.

62. In "Roads: their construction and maintenance," by Greenwell and Elsden, it is said that the curvature on a first class road should not exceed 50 feet in radius, although in hilly or mountainous country it may be necessary to increase the curvature to a 20-feet radius, while Major Paul, R.E., "Road construction and maintenance" says that except in hills or mountains, sharp curves are never required, or very rarely, and on a cart-road they should not be less than 45 feet radius, and if they are less, the road should be widened to 26 feet clear at the curve. Whether the measurements are to the centre or edge of the road is not stated in the case of this or the next paragraph.

63. Byrne in "Highway Construction" says the radius of curves should never be less than 50 feet and the curves may be circular or parabolic, the deviations from the tangent in the latter case being less than in the case of circular arcs. The width of the wheelway on curves should be increased, the increase being one-quarter of the width for angles between 90 and 120 degrees, and one-half the width for angles between 60 and 90 degrees.

64. In streets sharp curves are unavoidable, since a rectangular block system will always form the basis of the plan and radii of from four to

twelve feet to the edge have to be used, the smaller for wide and the large for narrow streets.

65. Now that motor traffic has to be considered, such sharp curves as those of 50 feet radius cannot be regarded as suitable, and though circumstances may require the use of curves of 60 to 80 feet radius for hill roads, it will always be advisable to see whether easier curves cannot be provided. On roads in open country such small radii should not be allowed. The First International Road Congress held in Paris in 1908 decided that the radii of curves should be as great as possible, 50 metres or 164 feet at least, the curves being connected with the tangents by parabolic arcs; that the outside of curves should be slightly raised, but not so as to inconvenience ordinary vehicles, and that no obstructions to the view should be allowed at curves. Mr. Wakelam, County Engineer, Middlesex, suggests a radius of 125 feet for motor traffic. Less than 200 feet should not be allowed on new main roads in India, except hill roads and, as a rule, easier curves should be given. For other metalled roads 150 feet may be allowed.

66. Sometimes it is advisable to increase the width of the metalling at curves and to shift the crown towards the outer edge. This is the method adopted by the Los Angeles Highway Commission of 1910.

Fig. 17.
Shewing widening of road at curve

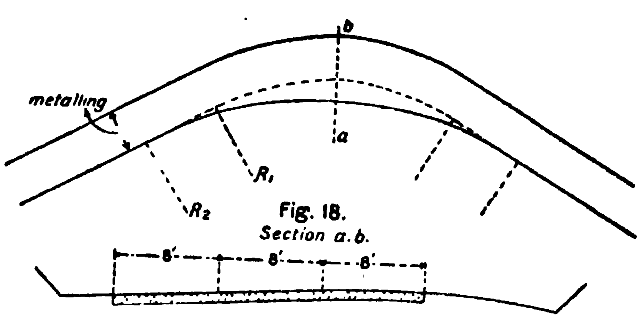


Fig. 18.
Section a. b.

In this case the 16-foot road is made 8 feet wider on the inside and the road surface is thus "banked" to some extent.

67. "Banking," or superelevation, means that on curves the outside of the track should be higher than the inner edge to neutralize the effect of centrifugal force, and to prevent a car from sliding or upsetting outwards. The formula generally used to arrive at the superelevation required is—

$$\tan a = \frac{V^2}{Rg}$$

where a is the angle of elevation, V is the velocity in feet per second, R is the radius of curvature in feet to the centre of the road, and g is the

acceleration due to gravity in feet per second. If instead of v the speed M in miles per hour is considered, the formula becomes—

$$\tan a = \frac{M^2}{15\,R}$$

Then for a curve of 120 feet radius and a speed of 10 miles an hour a cross-slope of 1 in 18 is required. The values of tan a for speeds of 10, 15, 20 and 25 miles an hour and for curves of 50, 100, 150 and 200 feet are given in the following table :—

TABLE IV.

Values tan a or cross-slope of road in tan $a = \frac{M^2}{15\,R}$

Radius of curve in feet.	Speed in miles per hour.			
	10.	15.	20.	25.
50, ...	$\frac{2}{15}$	$\frac{3}{10}$	$\frac{8}{15}$	$\frac{5}{6}$
100, ...	$\frac{1}{15}$	$\frac{3}{20}$	$\frac{4}{15}$	$\frac{5}{12}$
150, ...	$\frac{2}{45}$	$\frac{1}{10}$	$\frac{8}{45}$	$\frac{5}{18}$
200, ...	$\frac{1}{30}$	$\frac{3}{40}$	$\frac{2}{15}$	$\frac{5}{24}$

These figures indicate clearly the value of easy curves and low speeds.

68. In practice it will not be possible to adopt the "banking" indicated by this formula for such a speed, for example, as 15 miles an hour on a curve of 50 feet radius. It will be enough to adopt a cross-slope of 1 in 10 as a maximum and to limit the speed at severe curves. As mentioned in the chapter on Hill Roads, the slope will be inwards on salient and outwards on re-entrant curves. The road can often be widened cheaply at salients. At re-entrants the widening is more expensive, as the width of bridges between parapets has to be increased.

69. Curves for bridle-roads do not need to be as easy as those for cart-roads. For camel traffic curves should not be of less radius than 10 feet at centre and on all curves less than 20 feet, the road should be level for 20 feet. For mule roads a radius of not less than 6 feet is needed and the roads should be level for 10 feet.

70. At railway crossings the minimum curve should be of 200 feet radius in the case of all main roads and 150 feet in the case of other metalled roads, measured in each case to the centre of the road. The angle of crossing should not be less than 45 degrees.

71. Bridges and culverts are dealt with in the College Manual on Bridges, and it is not necessary to make more than a few remarks about them here.

72. The lineal waterway of road culverts is sometimes worked out by calculating the discharge from the drainage area by empirical formulæ and then assuming a high flood level and a velocity. The high flood level assumed should approximate to the high flood level of the stream, and the assumed velocity should not be taken at less than, or much more than, the actual or estimated velocity of the stream. This is not always carefully considered.

Take the case of a stream that is flowing at 7 feet per second in a broad shallow bed in which its depth is 2 feet. It would be wrong in this case to assume the high flood level as, say, 6 feet and the velocity as, say, 5 feet per second, for the velocity cannot be less than 7 feet per second, and will be considerably more if the stream heads up to anything like the extent assumed, heading up which may swamp cultivated fields or buildings or an encamping ground above the bridge site and may destroy the bridge.

73. Where there is no objection to flood waters being held back by a road bank some heading up is advisable and small culverts may be adopted, but unless they are well protected, there is always a chance of their foundations being scoured out. It is well, therefore, to take some trouble in collecting data as to the drainage or catchment area, the flood level, the velocity and the soil when culverts are being designed. A road engineer can often save a culvert by cutting the road bank, and can subsequently put in a metalled dip to act as a safety valve, or build an additional culvert ; but these expedients will not give him as much satisfaction as a well-designed culvert to start with. He should always give the down-stream side of his culverts deep foundations unless they rest on rock. With these and with liberal waterway to start with there will be no need later on for protective works which give trouble and cost money. "Bunds" above the culvert may have to be added if the stream develops a tendency to cut into the approaches, but the need for these may be independent of questions of waterway. Culverts are sometimes built with straight wings at right angles to the abutment and sometimes with splayed wings. The former are supposed to create eddies, but, as a rule, they answer very well, for the curve of the bank guides the stream.

74 The approaches of a culvert should be easy. They should never exceed 1 in 40 on metalled roads and 1 in 30 for earth roads, and the culvert should ordinarily be the full width of the road embankment. Many

roads are spoiled by the introduction of culverts which measure but little more between parapet kerbs than the width of the metalled portion of the road. This does not apply to bridges which are usully 16 feet to 20 feet between kerbs. The height of the roadway above bed level of the stream should be made as little as it can be consistent with other needs, and the road surface above the culvert and to distance of 20 feet on each side of it should be made level. Unless these matters are attended to, motor cars will bump as they pass over a culvert. Reinforced concrete slabs used instead of arches will assist in keeping down the bumps at culverts built over shallow channels in places where the road bank is low.

75. For carrying water for irrigation across from one side of the road to the other brick or masonry or concrete or pipe siphon drain of simple design are needed.

76. The various formulæ used for calculating the discharge from a small catchment area give different results. In the United Provinces it is usual, except in submontane tracts and for large works, take the discharge as follows :—

The maximum portion of rainfall which is likely to run off the catchment area in 24 hours may be taken as :—

9 inches for areas up to,	..	..	..	1 square mile.
6 " "	..	..	..	3 " "
5 " "	..	..	..	6 " "
4 " "	..	..	..	10 " "

a run of one inch being taken as equivalent to 27 cusecs, the higher values being applied to miles nearer the point of discharge, and the lower values to more remote points.

Thus for 8 square miles :—

1 square mile at 9 inches,	..	..	..	9
2 " " 6 "	..	..	..	12
3 " " 5 "	..	..	..	15
2 " " 4 "	..	..	..	8
8 square miles,	..	..	..	44 inches.

Discharge equals 44 × 27 cusecs = 1,188 cusecs. The results are very much the same as those which would be given by $D = 250\ M^{\frac{3}{4}}$ where D is the discharge in cusecs and M the area of the catchment basin in square miles.

77. Sometimes corrugated-iron pipe culverts or concrete culverts are used, and of late years reinforced concrete slab culverts have been adopted. Road bridges and culverts on main roads should be designed to carry a 15-ton steam-roller (which weighs 16·6 tons when ready for

work). For other roads the loads that bridges are likely to be called upon to carry should be considered in each case.

78. In places where heavy motor vehicles are licensed, notices need to be put up on each approach to a bridge stating what is the maximum axle-weight that the bridge can carry. An engineer needs, therefore, to study the carrying capacity of all the bridges on each road on which heavy motor vehicles are likely to be run.

CHAPTER IV.

THE CROSS-SECTION OF A METALLED ROAD IN THE PLAINS.

79. More land will be taken up for a road on the plains than for one in the hills, but occasionally the conditions will be reversed ; for there are localities in the plains in which these approximate to the conditions predominating on hill roads, and occasionally on the hills there are to be found open stretches of country where a cross-section suited to level country can be adopted.

80. For a metalled road in level country it is advisable to acquire a strip of land 100 feet wide, wherever this can be done, and to have the centre line of this strip coinciding with the centre line of the road. Sometimes the width has to be reduced, as when the road line passes through villages or valuable fields, which should be avoided as far as is possible, but not to the extent of making the road into a series of serpentine curves.

81. On the centre line of the land taken up is made an embankment of earth taken from borrow pits along the road boundary and from temporarily acquired land outside the road boundary. Not more than 12 inches in depth of earth should be removed from the temporarily acquired land, which will thus come under cultivation again in a short time, and the borrow pits in this case may be 50 feet long in the direction of the road, 5 feet apart, and of a width depending on the quantity of earth required for the bank in excess of that which can be obtained from the permanent borrow pits, which may be 50 feet long, of an average width of 4 feet, 2 feet deep, and at distances apart of 5 feet, the strip of land 5 feet wide between the adjacent borrow pits being intended to keep them from acting as a drain. In places it may be found convenient or necessary to convert them into a drain, but, as a general rule, in the country it is better to leave the barrier between adjacent pits. Near towns and villages borrow pits which hold water and form breeding-places for mosquitoes should not be made. The dimensions given above are intended only as a guide. Occasionally it may be advisable to make the borrow pits on the permanently acquired land wider or shallower than abovementioned.

82. The embankment should be 30 feet wide at formation level, with side slopes of 2 to 1, and it should ordinarily be 18 inches higher than flood level, including any afflux, and 12 inches to 18 inches higher than the level of the country where this is higher than flood level, but

the top of the bank should not follow slavishly the undulations of the ground. As explained in dealing with the longitudinal section and with gradients, the formation line should have easy gradients, and these it cannot always have if it runs parallel to the undulations of the country. Depressions must be filled and tops of hillocks and spurs removed in order to secure easy grades, so the cross-section of the road will vary throughout its length, the bank being sometimes some feet above ground level and sometimes 18 inches or 12 inches above it, and occasionally there will be no bank at all as in cuttings, or where dips or Irish bridges are made, and sometimes a long length of road may be made with scarcely any bank at all, if any, as in situations where the spill waters of a large river are met with and there are not enough funds available for building sufficient bridges or culverts.

83. On the formation is laid the metalling of kankar, or stone, or other material, the object being to provide as smooth, and as firm, and as water-tight a covering to the road as possible. Ordinarily the metalling will have a width of 12 feet, except in towns, but in the case of roads on which the traffic is light the width is sometimes 9 feet, and occasionally 10 feet, and near towns, or in places where there is heavy traffic, it may even be 30 feet. A width of 12 feet has been adopted as a standard for roads in the United Provinces on which there is a fair amount of mixed traffic. It is not a good width for heavy traffic, in view of the fact that a width of about 16 feet is required to enable two carts to pass each other, without leaving the metalled surface and tending to damage its edges, but it is enough for roads with average mixed traffic.

84. Roads 9 feet wide have a reputation for "tracking" or forming "ruts" very easily; this does no harm where carts alone are concerned, and the road is easily repaired at intervals by cutting out the ruts and refilling them, once in three or four or more years, but ruts interfere much with fast traffic and become dangerous when they are deep, and a nuisance when loose road metal is spread on them in order to divert the traffic. A partial remedy is to widen the road, but this is not always effective, for in certain conditions of traffic, (*e.g.*, where the traffic is slow and all in one direction as from small villages to a central mart) it is not so much the narrowness of the road as the nature of the traffic that leads to tracking and a 12-foot road will track as readily as a 9-foot road. On the whole, however, the 12-foot road is to be preferred and it should not cost more in the end than the 9-foot road if it is properly looked after, after being thoroughly well consolidated to start with.

85. The thickness of the road metalling should not be less than two coats of $4\frac{1}{2}$ inches each, which will consolidate to about 3 inches each when

rolled or rammed. The resulting thickness depends on the quality of the material used and the thoroughness of the consolidation. The two coats of $4\frac{1}{2}$ inches will be sufficient for ordinary traffic if laid on well-made banks of good earth, but if the earth is easily compressed, or the soil is spongy, it will be necessary to put down in addition a soling, or foundation, course of tightly-packed bricks, or stone, or block kankar, or other material, and sometimes it may be necessary to provide for the drainage of the bank or of the soil below. Two 3-inch coats (as laid, not as consolidated) are sometimes suggested for a new road without a foundation, but it is not advisable to adopt so thin a coating, for a third coat has to be added almost immediately as special "renewal" in order to prevent the complete destruction of the road, and the result is not as satisfactory as if the work had been properly done at first.

86. It is advisable at this point to review briefly the history of road construction and to trace the improvements that have been made since the close of the 18th century.

87. The first roads of which there is any authentic record are these in the Assyrian Empire constructed about 1900 B. C. These roads radiated from Babylon, and it is said that the remains of one can be seen between Baghdad and Ispahan. It was not, however, till the time of the Roman Empire that roads were built on a large scale.

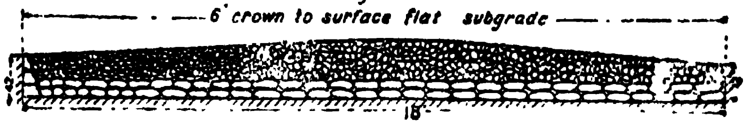
88. Roman roads, very straight and regardless of gradients, and made usually for military purposes, were not banked, but were built up after all loose soil had been removed and a solid substratum reached. On a foundation of large stones was placed a layer of broken stone set in mortar, and about 9 inches thick, over which was another layer 6 inches thick of mixed stones, broken brick and pottery, set in mortar and topped by a pavement of large stones of which the joints were filled with mortar. Sometimes piles were driven in order to make the foundation stable and sometimes more layers of material than are mentioned above were used, so that the road was as much as 4 feet thick in places ; but this was not usual.

89. These roads were allowed to fall into disrepair during the middle ages and the condition of all roads in Europe in the 17th century was bad, being better, however, in France than in England, where, in some places, the rough materials were laid in a narrow line not exceeding 7 feet or 8 feet in width, and of great convexity, forcing carriages, for convenience or for safety, to keep to the middle and soon wearing into deep ruts. In France before 1764 the metalled roadway was generally 18 feet wide, with a depth of 18 inches at the centre and 12 inches at the sides, and it consisted of stones laid flat in two or more layers as a foundation. On this foundation a layer of small stones was laid and beaten down and the

surface of the road was formed with a finishing coat of stones broken smaller than those immediately beneath.

Fig. 19.

Early trunk road



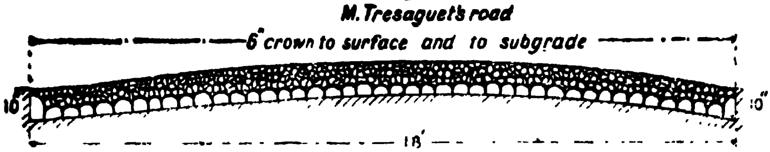
As the roads were till 1764 maintained by statute labour and repaired only twice a year, it was necessary to make them about 18 inches thick, as with less depth they would have been cut through and destroyed in a few months.

90. The suppression of statute labour in 1764 led to a change in design, the depth being reduced to such dimensions as were enough for that roads on the improved plan, and repaired under a system of constant maintenance, were made at less than one-half of the cost of the old roads and lasted for ten years.

M. Tresaguet's section was as follows :—

Fig. 20.

M. Tresaguet's road

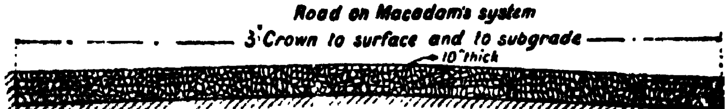


91. The bottom line or, as it is styled in American practice, the sub-grade, was parallel to the surface at a depth of 10 inches below it, a foundation of stones was laid edgewise and beaten to a rough surface, and over this a layer of smaller stones was laid by hand and beaten and broken coarsely with a large hammer, the finishing layer over this being of roughly broken stones, the size of walnuts, spread with a shovel to a depth of 3 inches, none but stone of the hardest quality being used. The cross-slope was 6 inches in the width of 18 feet.

92. Later on, about 1820, the Macadam system attracted some attention in France, and the good results of using sharp angular broken stone in consolidating the surface was recognised, leading gradually to the official adoption in 1830 of this system for the construction of roads.

Fig. 21.

Road on Macadam's system



93. Macadam passed his early days in America, but returned to Scotland when 27 years old, in 1783, and from 1798 till about 1815, when he was made surveyor of roads in Bristol, he travelled about in England, as often as he had leisure, to make notes on road-work. He noted that the roads were extremely bad in all parts of Great Britain and that very little improvement took place in them between 1798 and 1815, which he attributed to the ignorance of the persons who had charge of them and the total want of science used in their construction. He saw that the materials were so applied that the roads were all loose, and carriages, instead of passing over them, ploughed them, which was due to the bad selection of the materials and the bad preparation and unskilful laying of them.

94. In Bristol he found opportunity for putting into practice the improvement in road-making which he had evolved and which he had previously experimented with successfully on a small scale. This was to put sharp angular broken stone on a road and let it unite by its own angles, under the influence of traffic, so as to form a hard solid surface. The stone was in cubical pieces about 1½ inches to 2 inches cube, or 6 ounces in weight, broken from larger pieces, and was spread so as to form a layer about 10 inches thick over the road surface after this had been shaped and drained where necessary. The road bed was made parallel to the road surface, no foundation was used, and the use of binding material was not allowed for filling up the interstices in the metal, which was left to work in and unite by its own angles by means of the traffic, the material being regularly raked during the process of consolidation.

95. The cross-slope was just sufficient to cause the rain water to run easily off the surface into the side channels, that is about 1 in 36, for Macadam considered it a mistake to make the crown of the road very high, a proceeding which induced the traffic to follow the centre of the road as the sides were steep, and to wear it into holes from which the water could not escape. He held that the flattened surface which he adopted would drain better than the surface which had a greater crown. As remarked above, he adopted no foundation for his roads, for he believed in an elastic road bed. Associated with the period in which Macadam demonstrated the success of his method of construction are the names of others who helped to further the principles of good road making as Edgworth, an Irish proprietor, and Foster of Bedfordshire.

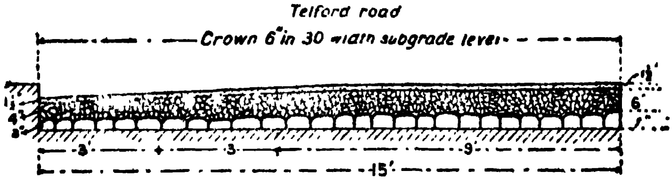
96. It was also early in the 19th century that Telford began the work that has made him famous. He did not, as Macadam did, believe in an elastic road bed, but considered it necessary to separate completely

the road metalling from the sub-soil by a firm and regular bottoming or foundation. Unlike Tresaguet and Macadam he did not make the road bed, or sub-grade, parallel to the road surface, but made it horizontal; and over it, when these were available, he placed a close firm handset pavement of stones of varying sizes. In some cases they were 7 inches in depth in the middle of the road, 5 inches at 9 feet from the centre, 4 inches at 12 feet and 3 inches at 15 feet. They were set on their broadest edges lengthwise across the road and the breadth of their upper edges was limited to 4 inches. When they were in position, all the irregularities of the upper part were broken off by means of hammers and all the interstices were filled with stone chips firmly wedged or packed by hand, with a light hammer, so that when the whole pavement was finished there was a convexity of 4 inches in the width of 30 feet. When stones were not available gravel, or chalk, or other local materials, were used to make a perfectly firm and regular bottoming to receive the top metal and to prevent its coming into contact with clay.

97. The middle 18 feet of pavement were coated with hard angular stones to a depth of 6 inches. Of these, 4 inches were first put on and worked in by the traffic, care being taken to rake in the ruts until the surface became firm and consolidated, after which the remaining 2 inches were put on. These stones were broken in pieces as nearly cubical as possible, so that the largest piece, in its largest dimension, passed through a ring of $2\frac{1}{2}$ inches inside diameter and weighed about 8 ounces. The paved spaces on each side of the middle 18 feet were coated with broken stones, or well-cleaned gravel, up to the footpath or other boundary of the road so as to make the whole convexity of the road 6 inches from the centre to the sides, and over all was put a layer $1\frac{1}{2}$ inches thick of good gravel free from clay and earth.

Fig 22.

Telford road



98. It was the complete separation of the road metalling from the sub-soil by a firm and regular bottoming that Telford insisted on as necessary, for he says, "particular attention should be paid either to find a naturally dry bottom for the roadway or to construct one, and avoid as much as possible suffering the workable materials coming into contact with the clay. And this may always be accomplished by means

of gravel, sand, vegetable soil, chalk, or bottoming stones; but the bottoming should be made perfectly firm and regular, so as to receive the top workable metal of equal thickness." Thus, though he always advised a paved bottom when it could be laid, many pieces of road were made under Telford's direction without the paved foundation with which his name has been associated. It is not unusual to find a road without a foundation spoken of as a Macadam road, and one with a foundation spoken of as a Telford road, and, in one case, in which the central portion had a foundation and the sides had not, the road was described as a Telford road with Macadam wings. Outside road literature the term Macadam has come to mean broken stone and a macadamized road is generally understood to be one made of broken stone, waterbound. It is only in road literature that the distinction between a Macadam road and a Telford road appears.

99. Most engineers now favour the adoption of a foundation on the ground that it reduces wear in the lower parts of the road, prevents clayey sub-soils from working upwards into the road crust, and keeps the broken stone from working down into the sub-soil. They do not, however, always make the road bed horizontal, but often curve it to correspond to the curve of the road surface. Both forms are used, and the foundation is sometimes made of cement concrete which may even be reinforced when the road has to carry very heavy traffic, as in London and other large cities.

100. Metalled roads are not now always made 10 inches to 12 inches thick (*see* paragraph 85), but it is not advisable, even on the best soil, to have a new road less than 6 inches thick when consolidated. A road 4 inches thick has been known to give excellent service even under heavy traffic at Bridgeport in America, but the conditions in this case were said to be very favourable.

101. Attempts to adopt a formula by which the thickness of the road metal can be calculated have not been successful. In the case of buildings it is possible to calculate, in a way, the pressure on the soil below the foundations and so to fix the width of the foundations. In such cases, the pressure is usually considered to spread at an apex angle of 60°; but this angle is sometimes taken as 90°. The Massachusetts Highway Commission in 1901 assumed the pressure of a wheel on a road to be uniformly distributed over an area equal to the square of twice the thickness of the layer of broken stone, so that if t = the thickness of the stone in inches, w = the maximum weight in pounds per wheel, p = supporting power of the soil in pounds per square inch—

$$t = \sqrt{\frac{w}{4p}}$$

102. The formula is not quoted here for adoption in designing roads. As Baker says in "Roads and pavements":—"It is not wise to attempt to find a mathematical relation between the load on the wheel and the resulting pressure on the earth, since neither the angle of the cone nor the distribution of pressure on the base of the cone are known. It is reasonably certain, however, that the supporting power of crushed stone road varies as the square of the depth. This is an important relation to bear in mind when a road is to be strengthened."

103. The question of the shape of the road profile in cross-section is one that has led to some discussion. All agree that, for roads in level country, the crown should be raised more or less above the edges, which should be on one level, but they differ as to the amount and form of the convexity. The amount will naturally vary with the materials used, and, at present, only metalled roads are being considered. Telford said that 30 feet should be allotted to the roadway, to be formed of one regular convexity, a segment of a flat ellipse with a fall of 6 inches from the centre to the side channels, but his specifications do not always follow this. Macadam said that he had generally made roads 3 inches higher in the centre than at the sides when they were 18 feet wide. He considered that a road should not have a high crown, because much convexity forced the traffic to the centre of the road and wore it into ruts. With a crown of 3 inches in a smooth and well-made road 18 feet wide, or 1 in 36, the water, he said, would run off very easily and carriages would travel nearly upright.

104. Other authorities recommend a segment of a circle, or a parabolic curve, or, again, two planes inclined at a slope of from 1 in 24 to 1 in 36, and connected at the crown, for a length of 6 feet, by a segment of circle having a radius of 90 feet or more. Some give elaborate formulæ for calculating the crown in terms of the horizontal slope of the road, and others suggest various offsets from a horizontal line tangential to the crown which are intended to ease the steep slope of a convex curve near the edges of the road and prevent its being too flat at the crown.

105. The following rule gives a good section for a road with side gutters. Divide half the width of the roadway into four parts and, starting from the centre, give a fall of ·02 feet per foot to the first part, ·03 feet per foot to the second part, ·04 feet per foot to the third part, and ·05 feet per foot to the fourth part near the edge of the road. *See* also paragraph 370.

106. In the United Provinces, the authorised section is represented by two inclined planes sloping at 1 in 36 and meeting at the centre of the road. In practice the apex is slightly rounded off during consolidation.

107. The surface slopes of the various sections referred to are shown in the accompanying table, assuming the curves to be made up of four planes :—

TABLE V.

Curvature of cross-sections.

	Rise in 15 feet.	1st part.	2nd part.	3rd part.	4th part.
Rule, ...	6·3″	1 in 50	1 in 33	1 in 25	1 in 20
Ellipse, ...	6·0″	1 „ 237	1 „ 74	1 „ 36½	1 „ 11¼
Parabola, ...	6·0″	1 „ 120	1 „ 40	1 „ 24	1 „ 17
Segment, ...	6·0″	1 „ 118	1 „ 40	1 „ 24	1 „ 17
Two planes, ...	5·0″	1 „ 36	1 „ 36	1 „ 36	1 36
„ „	6·0″	1 „ 30	1 „ 30	1 „ 30	1 „ 30

It will be seen that the ellipse is very flat at the crown and steep at the edges, the parabola and segment, which are practically identical, are also flat at the crown, the rule gives a very workable section, while the inclined planes have the merit of uniformity. They are, however, condemned by several authorities and St. Clair Wilkins writes in his "Treatise on Mountain Roads":—

"If the sides of a road are made flat they will not keep so. This method leaves no cushion for wear on the sides of the road. The segmental section of Mr. Telford is preferred. It is true that with the curved section the nearer a vehicle approaches the gutter the more it leans over, whereas with the flat-sided road the inclination is the same; but with a slope of 1 in 30 the inclination is slight, and with a curved surface a greater breadth of road approaches the level than by the other plan, besides all coachmen keep as near the centre as they can when driving over country roads." As a matter of fact the Telford road has a much greater slope than 1 in 30 near its edges, though the average slope is 1 in 30, a very different matter.

108. In practice the two plane section has been found to answer very well in the United Provinces when it has been properly made by thoroughly ramming the edges of the road before the centre is rammed. Otherwise, the road has a tendency to get flat during consolidation. In effect, the road when finished may be said to consist of two planes slightly rounded at the crown, for there is never a marked central ridge on the finished road. The uniform and easy slope on each side prevents the formation of furrows, or gullies, at frequent intervals such as are

to be seen on convex roads on which the drainage runs rapidly down the steep marginal slopes, and this is specially the case where roads are made of kankar.

109. It should be borne in mind that regularity of section and evenness of surface are of more consequence than slight differences between one curve and another, and care should be taken to see that these are attained when the road is made. This regularity of section and evenness of surface are more easily secured when two inclined planes are used than when convex surfaces are specified, and there is another reason why two inclined planes are to be preferred to a convex curve in Indian roads. A convex curve drops rapidly near the outer edges of the road, and, as in most Indian roads gutters are not used, except in towns and hill roads (the road consisting of the central metalled portion and two earthen shoulders or "patris"), the steep marginal slope of a convex profile, of the whole width of 30 feet, would let the rain water cut up the outer edges of the earthen shoulders and reduce the effective formation width. In the case of a road that is metalled throughout its width a convex section can sometimes be used with advantage, for it gives a deeper gutter and so prevents the drainage from spreading on to the road, but it cannot be used on a normal Indian road without damage to the earthen shoulders or "patris." These should have the same slope, 1 in 36, as the central metalled portion.

110. The side slopes of the earthen embankment will usually be 2 to 1, but this may be varied if the soil, or the height of the bank, or the locality, require it. It is not always necessary to turf the banks, or to sow grass on them, or to pitch them with stones, or block kankar, or to make masonry or dry stone drains down them; but each of these protective measures may become necessary on occasion.

111. At intervals earthen platforms at road level, but projecting beyond the 30-foot bank, will be required for the purpose of stacking maintenance metal. These may have a surface area of 45 feet by 10 feet and thus be capable of holding 200 cubic feet of repair metal if the sectional area of the stacks is made 5 square feet. The platforms are usually made opposite each mile and furlong stone, so 1,600 cubic feet of repair metal can be stacked on them in each mile.

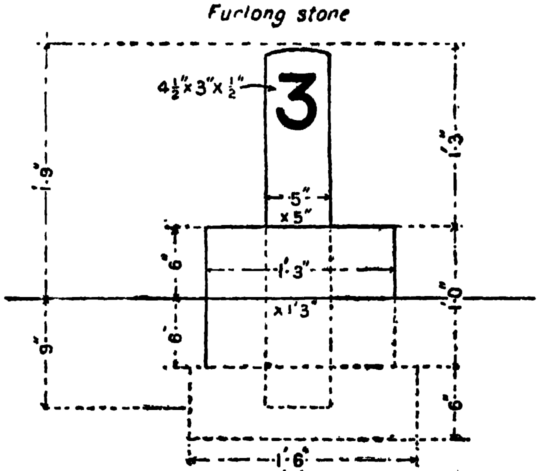
112. Railings are not ordinarily required on roads in level country, but occasionally there is need for them and many varieties are used, from banks of earth, or sundried bricks, to railings made of reinforced concrete posts, or stone posts, with wire or gas pipe horizontals, or crossed wire. The use of wooden railings is not recommended.

113. Culverts and bridges are treated of in the College Manual on Bridges and are referred to in Chapter III., paragraph 71 above.

114. Furlong-stones should be built on platforms of earth projecting beyond the 30 feet bank. They will ordinarily be of stone 5 or 6 inches square and about 2′ 6″ long of which 1′ 9″ will be above ground level and 9 inches below ground level, the bottom 3 inches being set in concrete 1′ 6″ × 1′ 6″ × 6″ and the next 12 inches in brick-work in lime mortar 1′ 3″ × 1′ 3″ × 1′ 0″ of which 6 inches will be below and 6 inches above ground level. There will thus be 1′ 3″ of stone above the 6 inch brick-work plinth, and on one face of this stone will be cut the number of the furlong in a figure 4½ inches high by 3 inches broad by ½ inch wide, so as to be visible from a distance. The details of the plinth, etc., can be varied. Sometimes a truncated pyramid of *kankar* is built round the plinth and whitewashed. The figure on the furlong stone should be painted black.

115. Mile-stones may be of various patterns and may be of stone or cast-iron, those of stone being preferable. The latest pattern prescribed for use in the United Provinces is illustrated. Mile-stones should ordinarily be placed five feet from the edge of the road bank, but where the "*patris*" are narrow, the stone may be at 21 feet from the centre of the road. A border of one foot of earth should be left at the back and sides of the stone and the earthen platform sloped off at 2 to 1. *See* figures 24 and 25.

Fig. 23.
Furlong stone



116. Boundary pillars of stone are required at intervals along the road and, at all points, where there is a change in land widths. Such changes should be infrequent, but, whenever they occur, they should be recorded on a land plan signed by the Civil Officer. The stones should

be buried deep into the ground, with about 9 inches showing above ground, and their positions should be checked from time to time.

117. Trees are sometimes planted at the road boundary, where they are useless for shade for people on the road, and sometimes so near the edge of the road bank that they are hurtful to the road surface which seldom dries after rain. Their proper distance apart, across the road, depends naturally on the variety of tree planted out. What is to be aimed at is to shade the road surface while allowing it to get air and sunshine; and it will be found that a suitable distance for ordinary avenues is 18 to 24 feet from the edge of the metalled surface. *See* also Chapter X.

118. Whenever a cart track or unmetalled road crosses the main road, but is situated at a lower level, a properly graded approach should be made on each side at a slope of 1 in 30 to 1 in 50, according to circumstances, with a width of 30 feet for a road and 15 feet for a cart track. For railway crossings, *see* paragraph 70.

119. During road construction, and for inspection purposes subsequently, shelter for officers and subordinates is required, and if the sites for inspection houses have been definitely settled, it is as well to build these of permanent materials at once. An inspection house which is placed where two officers will halt together during inspections should have a common room and two bedrooms about 18 feet by 16 feet with dressing and bathrooms. The rooms in Upper India should be arranged to catch the east and west winds and there should be a pantry and godown that will not interfere with this. In less frequented localities smaller bungalows may be built. The number of out-buildings will depend on whether there are to be inspection quarters for a subordinate and rooms for *naukar* coolies, who will generally be given *naukar* cooly huts of semi-permanent materials and convenient centres, but are sometimes given shelter in the compound of an inspection house. A well should always be provided at inpsection bungalows, and wire gauze shutters to doors and windows should be given whenever possible.

GRAND TRUNK ROAD
SAMPLE MILE STONE.

Fig. 24

ELEVATION

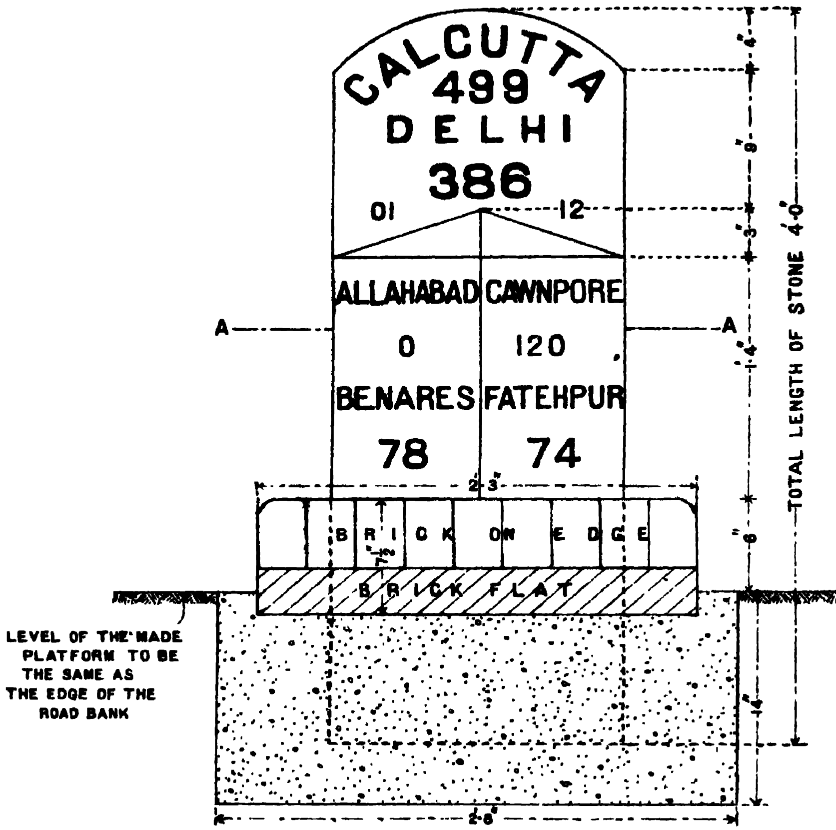
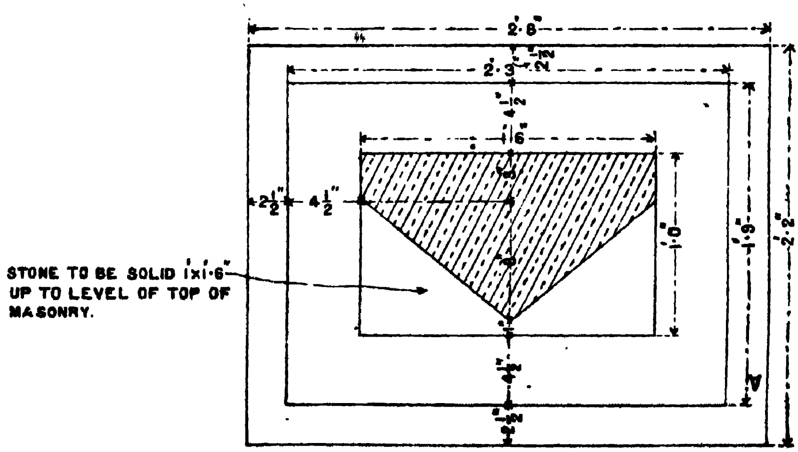


Fig. 25

SECTIONAL PLAN AT A.A.



To face page 43.

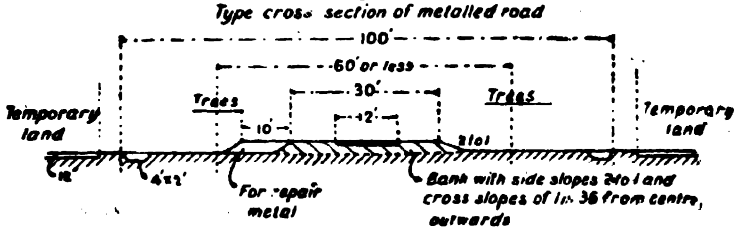
CHAPTER V.

SURVEY, DESIGN AND ESTIMATE OF A METALLED ROAD IN FLAT COUNTRY SUCH AS THE UNITED PROVINCES.

120. The road might be a new road or an improvement of an existing unmetalled road. احکام جاری

121. In the absence of standing orders or of special instructions, the engineer should decide to make the road of the section here shown and

Fig. 26.
Type cross section of metalled road



should make :—

(1) The land width, ...	...	100 feet
(2) The formation width,	...	30 ,,
(3) The metalled width,	...	12 ,,
(4) The side slopes, ...	...	2 to 1
(5) The ruling gradient,	...	1 in 40
(6) The minimum curve,	...	200 feet
(7) The cross-slope, ...	...	1 in 36

122. He should, if he can do so, get a subordinate who has an eye for country and with him he should make a preliminary reconnaissance of the ground to be traversed. The oftener he can go over it the better. Perhaps his other duties will prevent more than one or two visits. He should do his best. During his reconnaissance he should make as full notes as possible of every matter that may have a useful bearing on the project. If a good map is available, he should mark on it points through which the road must pass as, for example, a part of a river suitable for a bridge, or what the road should, if possible, avoid, such as valuable groves of fruit-bearing trees, and he should select one or more trial lines from which the final route will be chosen. His subordinate should make a survey embracing the selected trial lines and should record in his field-book and note-book full details of existing roads, railways, canals, irrigation channels, their levels, their widths. He should locate all prominent points by compass bearings where they are too far to be

measured by offsets. He should find out where quarries for road metal exist and should note all about the roads, or tracks to these. If there are no existing quarries, he should make enquiry as to the position of, and means of access to, new quarries. He should note the levels and positions of all adjacent masonry wells, for use as bench-marks, noting the water level in them, and also the levels and positions of any other masonry buildings suitable for use as bench-marks, and he should prepare a list of all these bench marks. He should ascertain the low water level and the high flood level of all streams, or flooded land, the drainage area of streams, the slope of their beds, the nature of the soil. As regards large bridges, he should follow the instructions given in the Manual on Bridges, taking a longitudinal section of the river bed and cross-sections at the bridge site, and at distances of a mile above and below it, noting that he should try to place the bridge at right angles to the direction of the river when in flood, even if the road has to come on to the bridge by a double curve, which may, in fact, prove satisfactory from an æsthetic point of view. In fixing the alignment of the road, he should take care not to introduce sharp curves into any part of it. The alignment should be marked at intervals by masonry pillars.

123. Where the final direction of the road can be fixed upon in the field, or from existing maps, the traverse line of the survey may follow the centre of the road and levels along the centre line can be recorded as the work proceeds; but when this is not possible, the centre line of the road must subsequently be plotted from the traverse line and the levels connected with it, and the final levels must be taken along the line thus obtained, unless they can be interpolated from the levels already obtained. These levels are often recorded at intervals of 100 feet, but where the ground has tolerably uniform slopes, and if the plan is to be plotted to a scale of eight inches to a mile, levels may be taken at every half furlong, using a chain of 66 feet, with intermediate readings where the nature of the ground requires. Levels for cross-sections should also be obtained, the number of readings recorded on each side of the centre line depending on the nature of the country and on the question of possible deviations of the centre line. Where the country is regular and with a gentle cross-slope, and where deviations are not likely to be required, it will be sufficient, for all practical purposes, to place a levelling staff at 50 feet on each side of the centre line and to observe the level of the ground. Irregularities of the ground will necessitate more readings, the object being to secure information that will enable the subordinate to lay before the engineer such full information as will enable him, in turn, to decide

on the formation levels of the road and to alter the alignment where necessary.

124. When an old unmetalled road is being improved by altering the alignment, easing curves, and raising the road surface, levels of the centre line of the old road and its edges are very necessary, in addition to levels of the ground, for it often happens that the surface of the old road is much lower than the level of the country ; but these need be taken only where the old and the new alignments follow practically the same line. Sometimes the new alignment will leave the old line completely, and when it does so, the levels of the old road are not necessary.

125. For the survey the subordinate will follow tha instructions given in the Manual on Surveying. He will probably need a chain, 10-foot rod and tape, a level and staves, a prismatic compass, or a plane-table, or theodolite, and, if he can get one, he will find a tacheometer may be used with advantage. Sometimes work can be helped in the field and in the office by the use of tracings made from the village field maps (*patwari's* maps) which are published by the Board of Revenue and can be obtained on loan from Collectors of districts, or purchased. These maps show every field and its number and are most useful. Drainage lines can be marked on them by getting villagers to show at which point of their field boundaries they let the water out into the next lower field. Levels for contours can be taken quickly by noting in which field and in what part of it the staff has been held and marking the point and its level on the map. Watersheds of catchment areas can be ascertained in this way. These maps are also of great use in preparing the land plans which are required to assist the Revenue department in assessing the land compensation payable for land required permanently or temporarily for the road.

126. For surveys of small areas section paper, known somstimes as graph paper, can be used when worked in connection with a chain, 10-foot rod, tape, flags and any instrument, however simple, that will give horizontal readings of 90 degrees. No drawing instruments are wanted, because all the lines needed can be drawn free-hand over the ruled lines which serve, too, as a scale for the main lines and their offsets. The south point can be ascertained by a reading on a watch or by noting the direction of the sun at noon ; and in this way the north point can be found tolerably correctly. If the hour hand on a watch is pointed towards the sun, a line bisecting the angle between the hour hand and XII. will point to the south.

127. The scale to which the road plan should be prepared will ordinarily, be that of the longitudinal section for which a convenient horizontal scale is eight inches to the mile, but if the village field maps (scale 16 inches = 1 mile) are used in preparing the survey, they should be used in preparing the road plan. Full information as to levels, bench-marks, etc., that has been collected during the survey, and is of use, should be given on the plan as well as on the longitudinal section. The north point should appear on all plans. Quarries should be indicated by arrow heads pointing to them, and their distance should be recorded. The road mileage should be very clearly shown and also any other items mentioned below which will not crowd up the plan too much.

128. The longitudinal section is plotted to two scales, the vertical scale being an exaggerated scale intended to show small differences of level more clearly than would be the case if the longitudinal scale were used for this also. The longitudinal or horizontal scale may be eight inches to the mile. The vertical scale may be twenty feet to one inch. Neither of these is an absolute scale. They may be varied in different projects. There is, however, an advantage to an engineer in keeping the same proportion between the horizontal and vertical scales, for, if this is done, the eye gets accustomed to the exaggerated gradients which, moreover, can be drawn by means of specially cut set-squares or by ordinary set-squares on which the exaggerated gradients are marked. On the longitudinal section should be shown the reduced levels of the country along the centre of the road and on each side of it, the levels of the existing road when there is one, names of villages whose land the road passes through, bearings of straight lengths of the new road, the radius, to the centre of the road, of all curves, the points at which the curves begin and end, all bench-marks, road, rail, canal and other crossings, flood levels, the nature of the soil, distances and bearings to quarries, and, in fact, anything that will prove useful to the man who makes the estimate and the man who arranges the contract and carries out the work. A blank form used for drawing longitudinal sections is given opposite this page. *See* also paragraph 132.

129. The formation line should now be plotted on the section, the paragraphs on gradients and on the cross-section, and the introductory general priciples being followed in order to provide longitudinal slopes that will not be too flat or too steep, or below flood level, or unnecessarily above it. In doing this the exercise of common sense and judgment are required. When the gradients have been decided on they should be marked on the section, as should also the formation levels, the heights of the

bank, the depths of cuttings. Care must, of course, be taken to see that railways and canals are crossed at suitable levels, and at angles of not less than 45 degrees.

130. When the longitudinal section is ready, the earthwork estimate can be prepared from it. If the stations have been plotted at intervals of 100 feet, the mileage will not fit in nicely with the sections, and it will be advisable to consider the estimate in stations of, say, 500 feet, or 1,000 feet, after calculating the quantities for each chain of 100 feet. If the stations are plotted at 66 feet intervals, or multiples of 66 feet, the estimate can be prepared by furlongs and miles. The quickest method of estimating quantities of earthwork is to use the form here shown:—

Station.	Height or depth. Feet.	Mean height or depth. H.	H^2.	$B \times H$ $B = 30$.	SH^2. $S = 2$.	$B + SH^2$ S. F.	L. feet.	Content C. F.
5	2·0	...	...	...	...	...	...	...
6	1·6	1·8	3·2	54·0	6·4	60·4	100	6,040
7	1·8	1·7	2·9	51·0	5·8	56·8	100	5,680
8	2·2	2·0	4·0	60·0	8·0	68·0	100	6,800

which may be modified to suit special cases. When an old road is being improved, it will be necessary to deduct, from the figures so calculated, the contents of the existing bank or to add something to allow for filling which is necessary when the old road has worn down below the level of the country.

131. Separate schedules should be made out for land compensation, for earthwork in bank or in cutting, for road metal collection and consolidation, for mile stones and furlong stones and boundary pillars, for culverts and bridges for inspection houses, *naukar* cooly huts, parapets, drains, gutters, etc., and for anything else that may be required on any particular road. Requirements will naturally vary with circumstances. When all that is needed has been calculated in detail, the figures of cost for each furlong or 500 feet or 100 feet may be brought together in a methodical manner. They should include all small works, such as culverts, but need not include big works, such as bridges, the cost of which can be separately shown. By grouping his estimated figures systematically, the engineer can watch the progress and the expenditure better than he could otherwise do. He should, in addition to this

distribution of cost, prepare an abstract showing the total quantities of each kind of work, the rates to be paid for them, and their cost.

132. In the chapter on hill roads a sample form is given showing how the work to be done in each chain can be brought together. A simpler form can be used in preparing an estimate for a road in the plains. Road plans and sections should be on sheets about 33 inches long by 13 inches deep, folded alternately to left and right in 8-inch widths, with a one inch margin at the extreme left for binding or taping; and if the depth has to be more than 13 inches, the extra depth should unfold away from the reader, and not towards him, one inch being cut off its length along the left-hand margin to admit of easy folding and unfolding.

133. If permanent pillars have been put down when the traverse line was being run, the engineer who has to line out the road for construction will have but little difficulty in picking up points on the line, but these cannot always be arranged for, and it may be found necessary to make out the centre line of the road, and the road boundaries, from bench-marks on wells or buildings and their bearings and distances from the plotted centre line or, again, from the fields shown on the village field maps.

134. The alignment should be done with a theodolite, and curves should be carefully marked out by one of the methods given in the Manual on Surveying, pegs being driven into the ground at each station shown on the longitudinal section with masonry pillars at distances apart of 500 or 1,000 feet as circumstances may indicate. The line should then be levelled over and the resulting levels compared with those on the sanctioned drawing, for if there are by chance any errors, it is well to discover them before construction is begun.

135. The land required permanently and that required for temporary occupation having been marked out and taken over from the revenue officer and the alignment and levels having been checked, the work of construction of the bank can be started. Methods of constructing banks are described in the Manual on Earthwork. Here it is sufficient to say that no earthen bank should be made without its sectional outline being marked out at intervals by means of profiles which can be made of bamboo and string, or of earth, and every bank should be made in 6-inch layers slightly higher towards the edges than at the centre, all clods being broken before the earth is thrown on the bank.

136. When the bank is ready, it is usually allowed to stand through a rainy season before the road metalling is placed on it as described under *kankar* consolidation and stone consolidation,

Name of Village

Gradient

Cutting or Embankment

Reduced Formation Levels

Reduced Ground Levels

Distances

0 1 F 2 F 3 F

No. 659 1500

CHAPTER VI.

HILL ROADS.

137. Before deciding on the alignment of a road in the hills the engineer should get a good map and study it carefully, and see if he can mark on it the general alignment he would select, assuming that there is nothing in the geological features to prevent the adoption of this line. He should then go over the ground to see whether the line could be followed, and in his reconnaissance he should be accompained by a subordinate whose usefulness will be great if he has a good eye for country and has previously been employed on work in the hills. Together they should study the locality, examine the suggested alignment, see if it leads them into difficult situations, try alternative alignments if it does, and fix on obligatory points which the road must pass through.

138. No map can make up for personal knowledge and the more thoroughly the reconnaissance is made, the better will be the final survey and alignment. Sometimes the first reconnaissance has to be made in new country and an aneroid barometer is needed in order to ascertain the relative heights of the hills that the road must cross.

139. Geological features should be carefully noted, existing and old established lines should not be hastily abandoned, the question of water-supply should be examined, and if the alignment chosen appears possible, the subordinate should proceed to mark it out on the ground.

140. In marking out a line two methods can be followed. One is the vertical system in which the point marked lies in the same vertical plane as the centre of the road, the other the horizontal system in which the point marked lies in the same horizontal plane as the edge of the road surface. The former is the method followed in marking out a road in easy country, the latter is the best method for marking out a road in a hilly country with steep slopes. Occasionally, as when the mountain road is to cut through a spur, the vertical system is most suitable. The horizontal system requires that pegs should be driven into the ground at points which, when connected up, give a trace of the road along the side of the mountain, and if a path is made along this trace, a person who walks along this path is following a narrow strip of the road (subject to small alterations) and ascending, or descending, at practically the same grade as the road. A line cut to connect pegs driven in on the vertical system will follow the direction and curves of the road, but will be at varying heights above or below its surface. For the vertical

system a theodolite or compass is required and for the horizontal system a clinometer, or Abney's level, or *ghat* tracer.

141. The College Manual on Surveying describes surveying instruments and the methods of using them, and should be referred to for information; but a brief description may be given here of a simple road tracer which can be made up by a carpenter and is mentioned in the College Manual on Roads, 7th Edition. A stout staff with a point to enable it to be driven firmly into the ground has a quadrant of card, or board, swinging in a vertical plane, attached to it. The quadrant is graduated round the arc and has a plumb bob depending from its centre. If the quadrant is turned and fixed by means of a nut provided for this purpose so that the selected slope coincides with the plumb bob, the upper radius, which can have two sights fixed on it, will read the desired slope and a rod marked at the same height as the centre of the quadrant can be held at any suitable distance, being moved up or down the hill-side by an assistant, while the surveyor, fixing the foot of the staff on the trace, looks through the sights and reads on to the mark on the rod. The foot of the rod will then be a point on the trace. This instrument, or any clinometer, would be used for a rough trace only, the final gradients being marked out with a level.

142. With the clinometer, staves and chain the surveyor would begin work from an obligatory point on the top of a hill, *e.g.*, a pass through which the road must go, and would work down the spur which had been selected after the first reconnaissance, putting in pegs at 100 feet apart, or 66 feet apart, or at smaller intervals if the nature of the ground required it, and connecting them up by a "*daghbel*," *i.e.*, a furrow in the ground. The reason for starting work at the top of a hill is that the ground gets easier as the lower slopes are reached and diversions and deviations can be made to enable the road to reach any point in the valley, while these could not be made with ease if the surveyor worked upwards towards the pass. The chances in working up are that the road would be either too high or too low for the pass. In the former case the grade could be eased, which would increase the length to some extent, but in the latter case it would be necessary to make a zig-zag. Now zig-zags are to be avoided in places where the slopes are steep, for a steep slope affords but little room to turn in. It is better to put them in as curves in easier ground lower down the hill.

143. It is not always necessary to look for a pass as on obligatory point, for very often a hill can be "turned" and the road may be able to go round it, without being any longer than the road, that would go

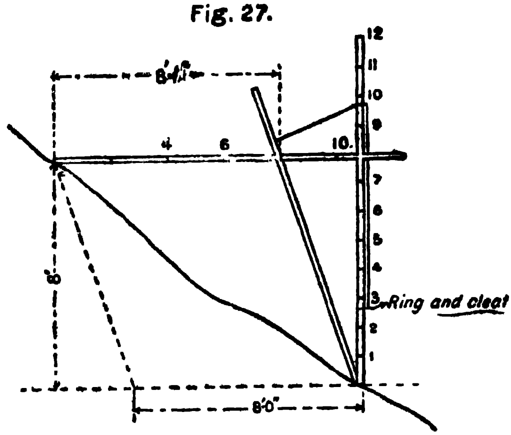
over it, thus saving rise and fall, and even if it is somewhat longer, the alignment round the hill may be better than the other, assuming always that both roads are equally suitable in other respects. Which has the best shade? Which passes nearest a village that must be near the road? Which has the best water-supply? Which is the easier to construct? Which is the easier to maintain? These are questions for consideration. Others will be suggested by the circumstances of each case, but they will not affect the main fact that the survey should start from the highest point chosen and work downwards.

144. The surveyor should, as he proceeds, collect information as to the soil and the slope of the hillside at each station, and on the correctness of the information he gathers will depend the correctness of the estimate subsequently made. He should judge how much of the road width will be cut out of the hillside and how much will be in bank, for it is not necessary to cut the full width except in a few places. He should note where retaining walls are needed and where the soil needs breast walls.

145. The following method, introduced by Captain H. S. Rogers, R.E., and described in "Road Construction and Maintenance" by Major E. M. Paul, R.E., affords a simple method of recording the quantity of cutting for narrow roads on steep ground and does away with the necessity for cross-sections. It was found especially valuable in arriving at the comparative cost of alternative alignments:—

"Assuming that the outer cutting edge is run with the clinometer and marked out, chaining is commenced at the top, the computing party

Fig. 27.



provided with a slope template working with the back chainman.

The template is used for setting off the estimated back slope on which the area of the cutting largely depends. It consists of a stout vertical batten ($2\frac{1}{2}$ inches by 2 inches) graduated in feet, and provided at the foot with a hinged or knuckle joint, into which is fitted a long light bamboo. To this bamboo arm a wire is attached, which passes over a pulley in the batten and ends in a ring for hooking over screws or cleats, placed so as to enable the arm to be set at slopes, with the batten placed vertically, of 1 to 1, $1\frac{1}{2}$ to 1 to, say, 4 to 1. To use it the template is set up by one man on the spot fixed by the back chainman. A second with a long straight bamboo marked at 4 feet, 6 feet, 8 feet from one end, (*i.e.*, the widths for the cuttings) and standing on the slope above the template, places one hand at the mark given (in the cases referred to usually 8 feet full cutting for a mule road); he then holds the bamboo high and horizontal, with his hand against the moveable arm, lowering the rod—maintained horizontal—until the end touches the ground slope. The height is then read from the vertical rod and recorded, together with the area of cutting and the quantity under the soil column. It then remains only to total and price the work at the end of the day. The field-book is ruled thus :—

Chain 100 feet.	Back slope.	Width Feet.	Height Feet.	Sup. feet area.	Soil in cubic feet.		
					Hard.	Medium.	Soft.
Brought forward,			...	...	10,270	18,980	25,460
19	3/1	8	6	24	...	2,400	...
20	$2\frac{1}{2}$/1	8	4	16	...	...	1,600
21	3/1	8	8	32	1,600	1,600	...
22	2/1	6	5	15	...	...	1,500
				And so on.			
Carried over							

In the remarks column entries can be made where streams are crossed, other details entered and any special points regarding the soil and excavation noted. Sufficient accuracy can usually be attained by dividing the work into *hard*, *i.e.*, soil requiring blasting; *medium*, *i.e.*, requiring blasting and jumper work; and *soft* or pick and jumper work.

146. For wide roads the method described above cannot be used, and in estimating for these, it is advisable to measure the front or natural slope in degrees, and to state the back slope in degrees, and to plot a cross-section at each station on which can be shown such retaining and breast walls as may be required, and from which the final estimate can be prepared.

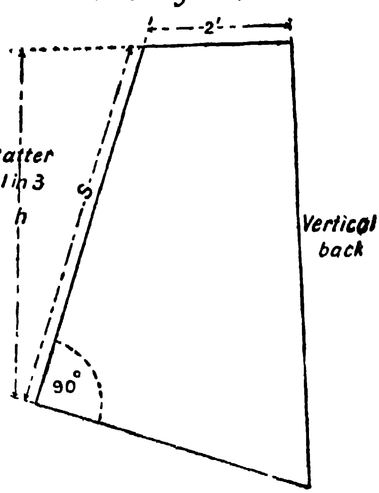
A table can be made giving the areas of the cuttings with various natural and back slopes for various widths of cutting, and with the

aid of this table the estimate of the excavation can be taken out very quickly. Such a table is given in Appendix I.

Table can also be prepared of the areas of retaining walls and breast walls. Specimen tables are given in Appendix I. These tables were prepared for use in the Second Circle of Superintendence, Buildings and Roads, Lucknow, by Mr. H. J. Oliphant, Executive Engineer, Naini Tal division, to whom the writer is indebted for them.

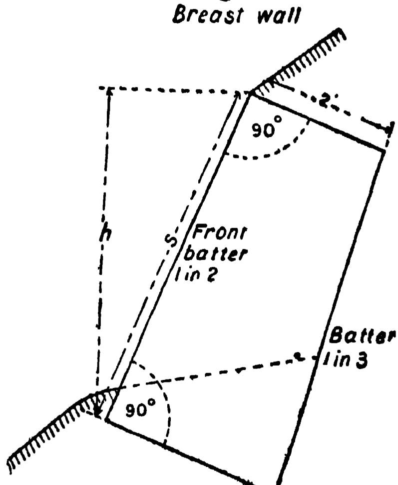
147. The tables for retaining walls, which are walls built at the outer edge of a road, are for the section here shown.

Fig. 28.
Retaining wall



Those for breast walls, which are walls built to support the hillside above a road, are for the section here shown.

Fig. 29.
Breast wall



148. It will be noticed that each section starts with a top width of 2 feet. The retaining wall has a vertical back and a front batter of 1 in 3. The breast wall has a front batter of 1 in 2 and a back batter of 1 in 3. The back should be left rough, some stones projecting further than others, and the "backing" of each wall, that is, the filling in between the wall and the hillside, should be of loose stone. The base line should be at right angles to the front which should be rough dressed and pointed, and there should be plenty of weep holes in the walls. Small stones will not make a good wall. The largest stones that can be handled should be used and there should be as many through stones as possible. Walls 6 feet high may be of dry stone masonry. Walls of greater height should have the top six feet of dry stone masonry and the rest of masonry in lime mortar. Other sections of walls can be used if they are preferred and sometimes the whole wall may be built in lime mortar.

149. Some engineers like to make a hill road with its surface on an inward slope, that is, with the outer edge on a higher level than the inner edge, and this is the form recommended in the College Manual on Roads, 7th Edition, which in paragraph 19 says :—

"In a road round a hill the cross-section should be a single slope inclining *inwards*, with a ditch on the inside; this is to prevent the road being washed away at its edge (which often has to be built up), and to avoid the danger, especially in turning a corner, of the passenger falling over the precipice. The drainage water, flowing from the hill above, is also intercepted by the ditch on the inside, which has cross-drains at intervals leading under the roadway to the face of the cliff. A catch water drain should also be constructed on the hill slope considerably above the road, to intercept the drainage and lead it to ravines and watercourses." And in paragraph 66 it says: "The shape generally given to the metalled road surface in cutting along a mountain side is a slope of 1 in 18 from the outside to the inside. It has been objected to this slope, that it converts the road into a drain, which is cut away and becomes impassable in heavy downpours, and in some of the Madras hill roads the slope runs from the inside to the outside. Both systems have their respective advantages, but on the whole, the inside slope is preferable when the cross-drains are sufficiently large and numerous, and the side drains rocky or properly protected by boulder paving. The usual practice is to adopt the outside slope until the drains are all built, and the side slopes have taken their bearings when, as a permanent arrangement, the road is finished and metalled with an inside slope. When, however, a road is carried through forests, the ordinary barrelled surface of roads in the plains may be adopted with

small cuts from the outer drain at every 30 or 40 feet, as the thick vegetation softens the rainfall and prevents the hillside being carried away by the drainage ; but on hillsides which are bare such a section would be unsuitable and a slope *inwards* should be given, more or less pronounced according to the steepness of the side slope of the hill and to the nature of the soil. The rule adopted on the Ramnagar and Ranikhet cart-road from the plains was to make the road surface *curved*, where the height of the outer retaining wall (if there is one) does not exceed 5 or 6 feet, and in all other places the entire surface to slope inwards with an inclination somewhat greater than the longitudinal slope of the road."

150. These views were not shared by Colonel F. D. M. Brown, V.C., Principal of the College, who, in the College Manual on Earthwork, 6th Edition, writes in paragraph 104 :—

"From the long experience I have had in the maintenance of hill cart-roads I consider the best section for a hill cart-road to be one that has the entire slope outwards, *with no inside drain.* This section is always adopted on bridle roads in the hills, the cost of maintenance of which is trifling, whilst for a cart-road the inside slope or a hogbacked section is always recommended. A hill cart-road is only about 10 feet wider than a bridle road, and the extra rainfall to be discharged for this small portion, provided it has an immediate outlet, will be found on calculation to be quite insignificant. Long experience on hill bridle roads and a few years experimenting on the Naini Tal tonga road, where the rainfall is excessive and the soil very bad, have proved to me that a hill road with an entirely outward slope and no inside drain is more easily and more economically maintained than with any other section. A side drain may be necessary in places to lead away a spring from a soft part of the road, etc., but these are the only exceptions, which pertain to the general engineering of the road. A slope entirely outwards or with a hogbacked section is especially unsuitable where the sides are liable to slip. The smallest slip of a few buckets full of earth or even the collection of a few leaves which allow the silt to accumulate will choke the inside drain, when the accumulated water will course down the road, causing much injury to the surface, and discharge itself over the edge in a strong stream, often at a weak place, which may cut away the bank or destroy a retaining wall. Similar damage may be done when a scupper gets choked. The inside drain is also contrary to one of the first principles of hill engineering, which is that water should not be allowed to accumulate, except of course in the main streams. As a matter of fact maintenance gangs invariably seek shelter during a heavy

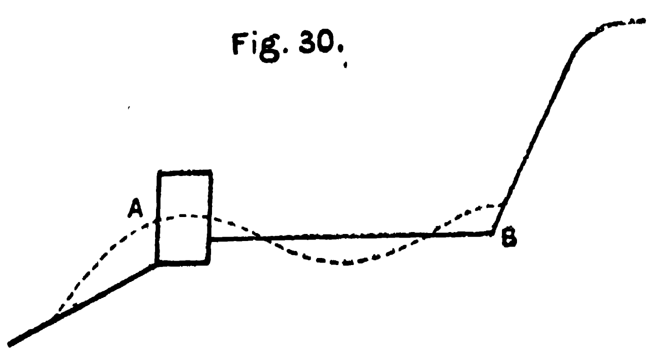
fall of rain, and it is during the actual falling of the rain that the chief damage is done to a road. Ten minutes after the rain has stopped the side drains are practically dry. The best arrangements therefore that keep the road properly drained during heavy rainfall should be adopted. The outside slope has not in practice been found inconvenient for fast traffic. The tongas travel downhill on the Naini Tal road at 10 and 11 miles an hour, without more inconvenience on the miles with the outward slope than on the miles with the hogbacked section. Any danger that may be anticipated from the centrifugal force at salient angles could not affect a vehicle until it was on the outside half of the road ; and then it would be immaterial whether the other (inner half) had a slope upwards or downwards. No faster traffic than a tonga is ever likely to travel on a hill road. The drivers have invariably told me that they prefer the outward slope, as they have only to look out for danger on one side, whereas on the old section they had also to take care to avoid the inside drain. An outside slope of 1 in 20 has been found in practice to be the most suitable, but with a small rainfall or a slight gradient it may be a little less. When a road is made with an outside slope the following precautions have to be borne in mind for its proper maintenance :—

(1) The outlet at A low enough to discharge the road drainage freely. This is often blocked by—

(*a*) The road wearing down in the centre.

(*b*) When slips are cleared away, a lot of the spoil is left at the outlet and thus a bank is formed at A (as shown in dotted lines) which obstructs the free flow of the road drainage.

Fig. 30.



(2) The earth from slips should be cleared clean away to the full width of the road, and not left banked up against the side by a lazy gang, as the width of the road is thereby reduced. When these precautions are not observed the road may assume the section

shown by dotted lines, when the centre of the road would become a water course and be thereby destroyed. The outlet A mentioned above refer to the 3 feet intervals left in the parapet walls to pass the surface drainage, the parapet walls being built in lengths of 10 feet with 3 feet intervals. By this arrangement 3/13ths of the parapet walling is saved, whilst they are equally efficacious as an outside fence. Or the parapets may be built in 7 feet lengths with 2 feet openings. Another advantage of the outside slope is that the road is widened by the 2 feet required for the inside drains, or the width of the cutting may be reduced 2 feet in first construction. As this is the inside 2 feet where the heaviest digging is required, the saving in first construction would be great. Scuppers at every three or four hundred feet also become unnecessary, as also their expensive maintenance. Should the soil be strong and the rainfall moderate there is no objection, except so far as the great increase of cost is concerned, to making the road with a hogged back and with an inside drain and scuppers, if this section is preferred; but with an excessive rainfall or in bad soil liable to slip or be washed away there is no question but that, from an engineering point of view, the outside slope should be adopted; and I am very sure if the engineer has to maintain any hill road after he has made it, he will be for ever thankful if he gives it an outside slope."

151. General St. Clair Wilkins, R.E., in his "Treatise on Mountain Roads," hardly touches the question of an outward slope, but discusses at length the relative merits of an inward slope and a convex section, which is the hogged back section written of by Colonel Brown. In this discussion he quotes the opinions of several officers. Thus Major Rose, Engineer of the Rawalpindi and Murree Road, writes in May 1865 in the Roorkee Professional Papers :—

"In most places the cross-section is now higher in the centre than at the sides; when it was first made, and the width was only 12 feet, it sloped inwards. From the experience of last season, when the rains were heavy and wheeled traffic considerable, it is evident that the rise in the centre is much better than having the highest point outside, even with a slope of 1 in 15 which it would have been difficult to give. In many places it was found impossible to keep the surface of the road in tolerable order, but where the road had been made with the rise in the centre and the earth had settled it remained, comparatively speaking, dry and firm." And in 1850 Major Kennedy writing on the subject of the cross-slope in connection with the road from Simla towards Tibet said :—

"It is well to know that some authorities on this subject have recommended the cross-slope of roads on declivities to run the whole

way from the outside verge to the inside, while others advise just the reverse, and not from the centre to each side. The chief object of the first recommendation is to prevent the corrosion of the outside verge by the surface water, and that of the second to prevent any accumulation of water in the water tables, but they both appear to be most objectionable in practice, as they necessarily throw every carriage off its level and bring an unequal portion of the load on the wheels of one side. They also give a longer run to the surface waters on the road. No professional man should permit so serious an inconvenience to be inflicted on the public. His ingenuity ought to provide a remedy of a different kind."

152. This is not a strong argument as far as the balance of carriages is concerned, for even on a convex section carriages must lean to one side or the other as they pass each other, but it is correct in saying that an inward or an outward slope gives a longer run to the surface water on the road. This is what Sir Henry Parnell said in his treatise, when dealing with the subject of roads in mountainous countries:—

"Attention in making the surface of a proper convex form is particularly necessary on hills, in order that the water may have a tendency to fall from the centre to the sides."

153. General St. Clair Wilkins further quotes the opinion of an engineer of experience who had charge of a large district containing several mountain roads and writes:—

"The system of sloping the roadway from the outer to the inner edge is faulty and liable to cause injury to the surface from the excess of rain water made to pass over the whole width of the road before it is carried off by the inner channel; the great slope necessitated in the transverse section of the road by this arrangement is also a very serious objection to carts proceedings smoothly along, and prevent the full width of the road being made use of in places where its dimensions are necessarily limited. Most of the Ghat roads in this district appear to have been formed on this principle, and their unsatisfactoy state during the rainy season is sufficient proof that it is ill-adapted to roads in localities where such a large rainfall takes place, and where the first object should be to drain the road surface as fast as possible by side channels on each side."

154. General St. Clair Wilkins after giving the opinions of several other officers, and mentioning cases in which the inward slope has been abandoned in favour of a convex section, argues that carefully made gutters will save damage to the outer edge of a new road, that a broad flat surface sloping inwards will wear easily and will turn into a gutter

for the passage of the drainage of the whole width of the road, that an inward slope if considered safe at salients must be considered dangerous at re-entrant angles, that a convex section has been adopted by common consent as the best section for a road in level and in comparatively level country, from the point of view of the engineer and of the user of the road, and that in mountain roads the convex section is, therefore, the one best suited for the traffic, for the drainage of its surface, and for economy of maintenance. He advocates the "segmental section" of Mr. Telford and says that finished mountain roads with a grade of 1 in 24 should have a crown of 5 inches for a width of 20 or 21 feet and of 6 inches with a grade of 1 in 20. The Telford section, it should be remarked, is not a "segment." It is referred to as a flat ellipse, and an ellipse has sides that are steep and a central portion that does not drain well. An ellipse is not the best form for a metalled road profile. The writer recommends that two planes inclined at 1 in 36, which are adopted for use in level country in the United Provinces, should be used for hill roads also, except at curves, the side drains being on one level and the meeting point or apex of the planes being rounded off during consolidation after, but not before, the edges have been thoroughly rammed and the sides have been compacted to a true slope. What should be arrived at is a true smooth finished surface, without an excessive slope at the edges, and this the two-plane section best gives.

HILL ROAD CROSS-SECTIONS.

Foundations may be necessary below the road metal in each case.

Fig. 31.
In ordinary soil

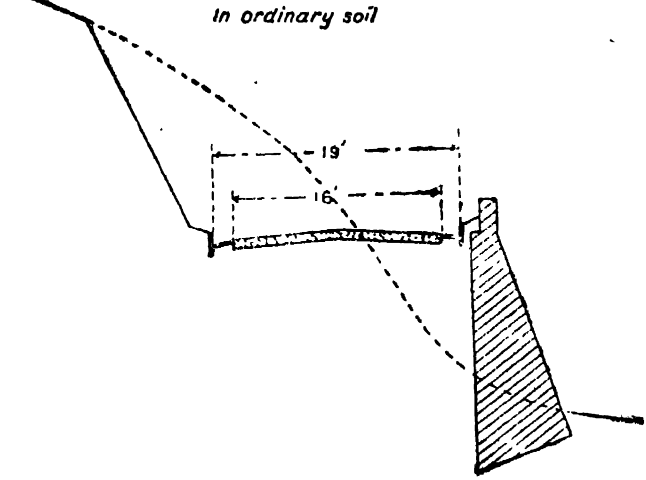
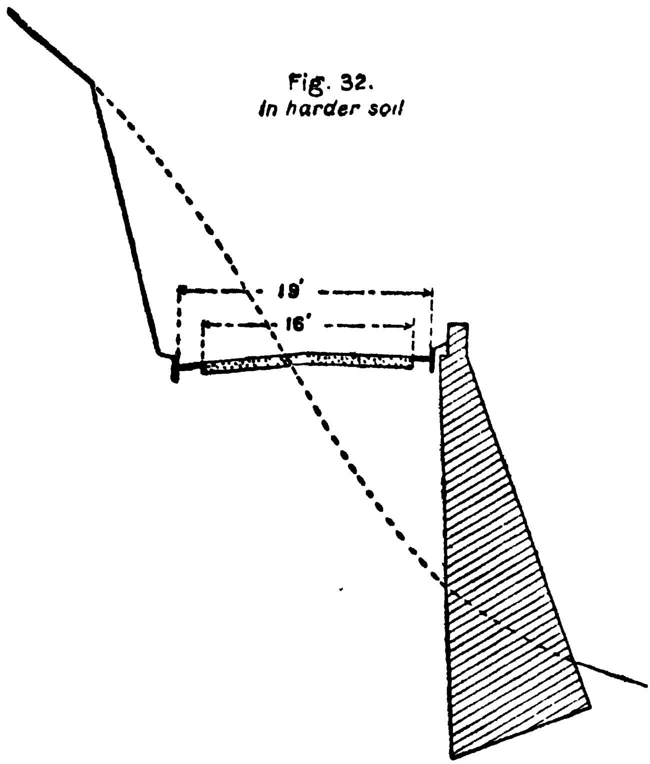
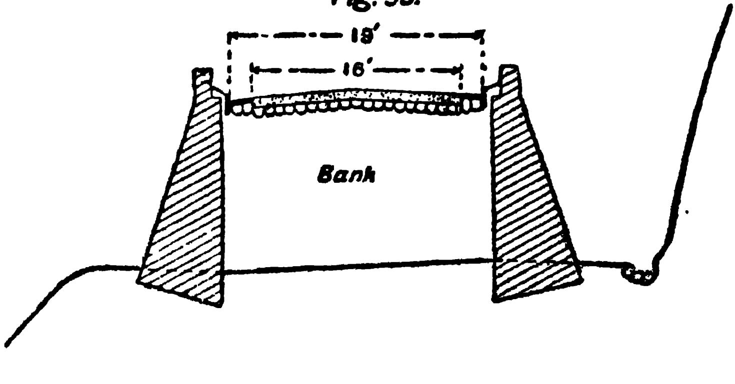


Fig. 32.
In harder soil



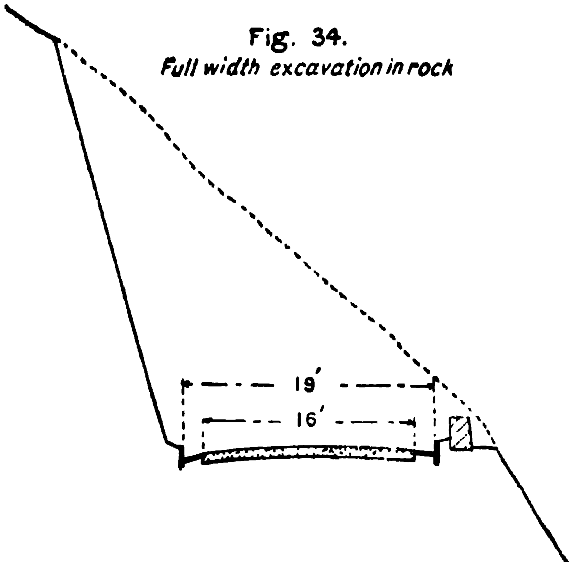
As an alternative the width of the excavation may be increased and the retaining wall reduced.

Fig. 33.



An exceptional section adopted to maintain an easy gradient.

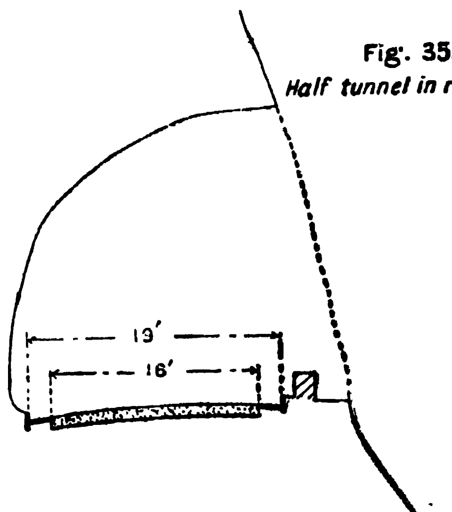
Fig. 34.
Full width excavation in rock



Gutters may, in this case, be shaped out of the rock.

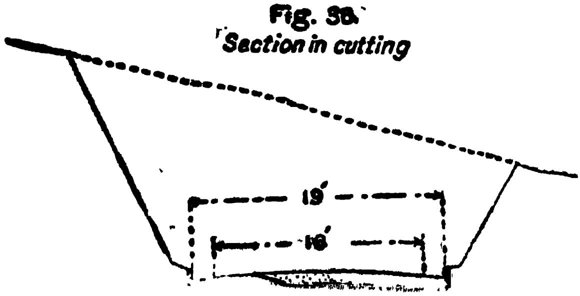
Fig. 35.
Half tunnel in rock

This section is more adapted to narrower roads.



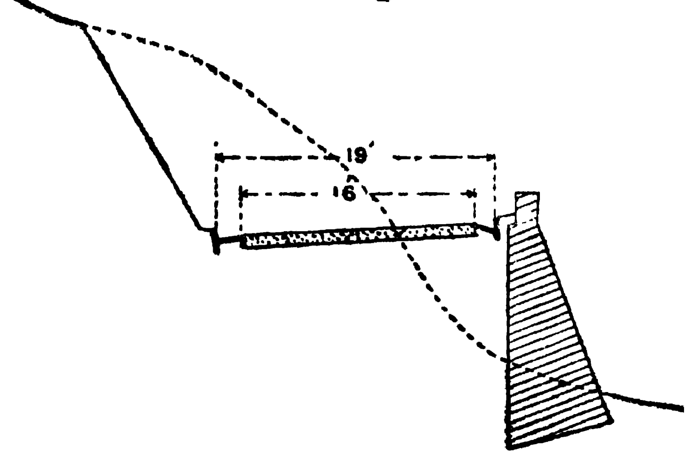
Gutters may be shaped out of the rock though shown as built with slabs.

Fig. 36.
Section in cutting



Slopes vary with nature of soil.

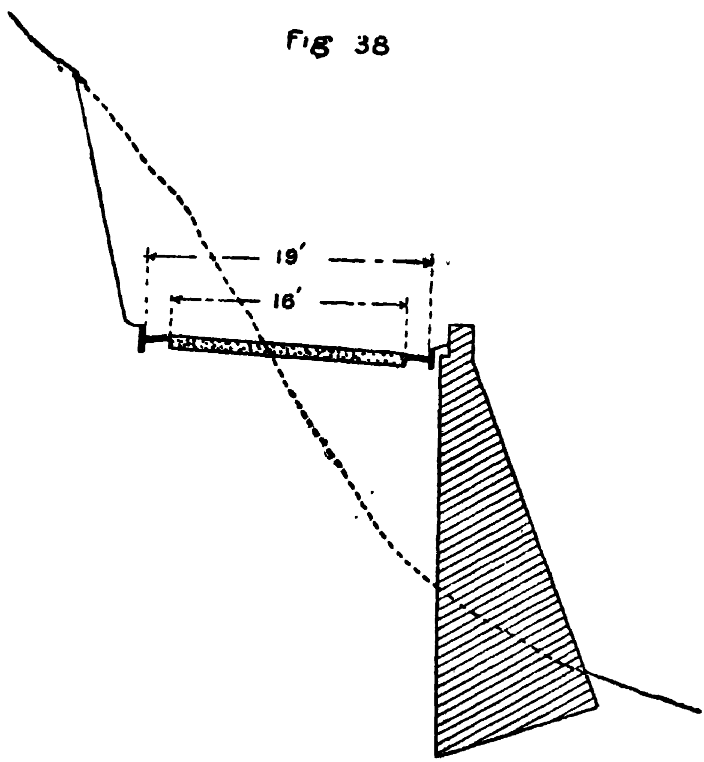
Fig. 37.



Section at salient curve showing "banking."

The road may be widened with advantage.

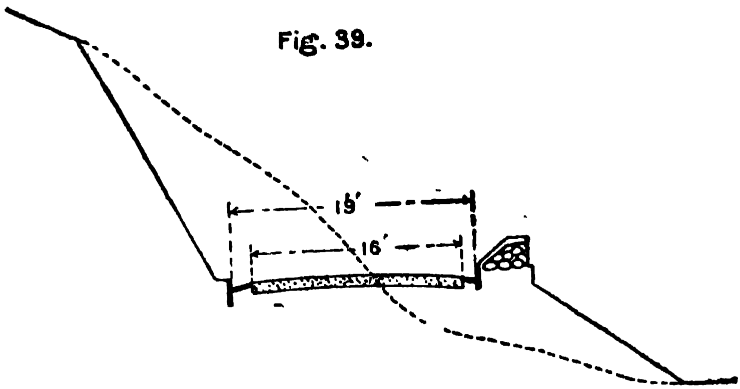
Fig 38



Section at re-entrant curve showing "banking."

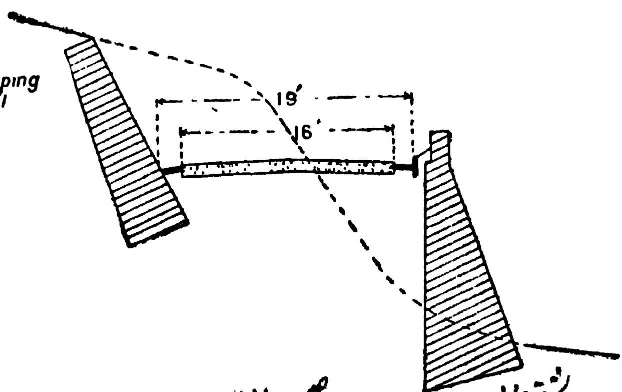
Usually there will be a bridge or culvert at re-entrant curves.

Fig. 39.



Section showing parapet wall of boulders and clay in easy situation.

Fig. 40.



Section showing breast wall and retaining wall.

155. At curves it is necessary, now that motor traffic has arrived, to "bank" the road giving it an outward slope at re-entrant curves and an inward slope at salient curves; these slopes merging into one or other side of the two-plane section at a distance of about 50 feet from the end of the curve. For particulars regarding "banking" the paragraphs on curves should be referred to.

156. The reasons that lead the writer to prefer for straight lengths, the two-plane profile, are that it is the section chosen for roads on the plains and it works out automatically from the two contrary sections of the inward slope and the outward slope. Neither of these could be used throughout the whole length of a hill road carrying fast traffic and one must change to the other, in the interests of the traffic,, as the road curves round salients and re-entrants.

157. A road surface of two planes inclined at 1 in 36 means, for a grade of 1 in 25, that the flow of the water down the road will be at an

angle of 35° to the centre line of the road. If it is desired to get the water away earlier, the cross slope can be increased at some inconvenience to the traffic; but this is hardly necessary. It will be seen that General St. Clair Wilkins makes the longitudinal grade and the average cross-slope the same, and this looks as if the water ran off at an angle of 45° to the centre line of the road which, however, it would not do, for the elliptical cross-section is much flatter near the crown than its average cross-slope. The two plane section gets rid of the water soonest. At curves the slope of the cross-section will depend on the amount of "banking" which will vary with the sharpness of the curve, as mentioned in the paragraphs on curves.

158. If it is desired to throw open a road to slow traffic quickly, and before it can be said to be finished, the principle of the outward slope may be adopted, with due precautions, as the road is easily made and has no inner drain or scuppers; but such a road, carrying as it does all the drainage of the hillside above it and of its own surface, must constantly be covered with débris, and if wide, roughened by the large flow of water over it, and it has to be completed by being properly shaped and drained before the engineer is satisfied with it, or can keep it in really good order.

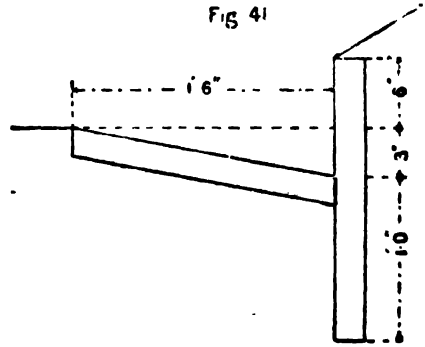
159. If, again, economy of construction is aimed at rather than the convenience of the traffic, a hill road that is meant for slow cart traffic may be made with an outward slope and without gutters. Such a road might be 12 feet or 14 feet wide between the parapet and the hillside. But if a finished cart-road is required for fast traffic, the width of the metalled roadway should be at least 16 feet with space for 18-inch kerb and channel drains on each side and a width of two feet to three feet on the outside for a substantial parapet: a total width of 21 or 22 feet.

160. In his "Treatise on Mountain Roads" General St. Clair Wilkins specifies a width of metal of 20¼ feet between gutters for which he allows nine inches for the outer and three feet for the inner gutter, with one and-a-half feet beyond the outer gutter for a dry stone parapet: a total width of 25½ feet; but a portion of the metalled surface in this case is encroached upon by guard stones placed at 4-foot intervals along the edge of the inner gutter at salient curves and along the outer gutter at re-entering curves. The width mentioned above, *viz.*, 16 feet of metalled road, is enough if kerb and channel drains are used. It is not necessary to cut the full width of the road except in special cases, for part can be in bank, supported sometimes by a retaining wall. Occasionally the full width is cut out as a half tunnel, but this is not often done for a 16-foot road, being more frequently used in the case of narrow roads

crossing a short steep cliff. Tunnels are not often used on roads. For descriptions of these the Manual on Railways should be consulted.

161. Side drains or gutters should be of the simplest pattern, and there is nothing to beat the ordinary kerb and channel shape wherever it can be used. Deep narrow drains are dangerous ; shallow wide rectangular drains take up too much room—and neither of these should be necessary if the drainage is got rid off as soon as ever this can be managed by means of scuppers under the road. Very large drains of masonry or reinforced concrete or wood may be required at special places above and below a road to catch the water before it soaks into the soil, which may be on the move, and to pass it off to firm ground below the road ; but these are not side drains. Experience of particular lengths of roads will show what kind and size of drain should be used. The general principle of construction of a side drain or gutter is explained here. This consists of a series of vertical slabs about 1¾ feet long by one foot wide by two inches thick which are sunk into the ground to a depth of one foot below the lowest point of the gutter, the bed of the gutter being the natural rock, shaped to section or slabs one and-a-half feet by one foot by two inches or small stones laid to a slope. The vertical slab is backed by filling between it and the natural soil or the parapet.

Fig 41



Sometimes boulders are used to form the bed of the gutter ; sometimes it is shaped out of the natural rock.

162. If the quantity of water to be carried off by gutter is small, the cross-slope of the road (1 in 36) can be continued to form the bed of the gutter, but if much water has to be drained off, the depth of the gutter must be increased in order to keep the drainage from spreading over the edge of the road. This can be done by increasing the bed slope of the gutter to as much as 1 in 6. And when gutters are used, the convex form of road profile, which does not work in well with the earthen "*patris*" of a road in level country, may be adopted if it is preferred to the section formed of two planes meeting at the centre of the road.

163. To keep down the quantity of water that will run in the gutters, the water from the outer gutter should be led off between adjacent lengths of the parapet wall and from the inner gutter by scuppers

under the road. Sometimes small Irish bridges are made for the purpose of carrying water across the road from the inner gutter, but these are out of place even on a bridle road and are certainly out of place on a cart-road.

Scuppers should, if possible, discharge over solid rock, or firm soil, so rocky spurs are good places for putting them in. They should be of simple design, a shallow trench covered with slabs being enough.

164. The engineer who ranges out the line of a hill road should remember that if he marks it out at the slope of the maximum gradient, he is likely to find that parts of the road when finished will have grades steeper than the maximum gradient. General St. Clair Wilkins says that the following rules should be observed in marking out a road of which the ruling gradient is 1 in 24 :—

1. All straight or slightly curved reaches to be laid out at 1 in 25.
2. At re-entering angles where a drain, culvert or bridge would occur the line to be taken across level.
3. At sharp-angled salients the chord of the curve to be taken through on the level.
4. At less prominent salients the chord of the curve to be taken through at 3 in 100.
5. At easy salients the curve to be carried round at 1 in 26.

"These rules," he says, "may be followed with advantage by the experienced engineer. The inexperienced engineer will do well to flatten his grades still more, otherwise his finished road will be sure to work out steeper than his ruling gradient."

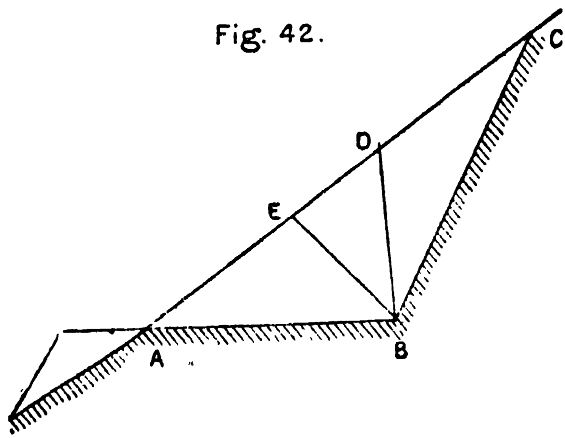
165. The line, before work is begun, should be clearly marked out with masonry pillars, one chain apart, and intermediate pegs, at 20-foot intervals, which should not be moved till the work is finished. Work can be given out to contractors in 5-chain lengths, but no contractor should be permitted to break ground in more than one chain at a time, work in the second chain being started when that in the first has been measured up and paid for. If this is not done, some contractors will finish all the easy work in a 5-chain length and refuse to do the more difficult work. It is not necessary to complete the full shape of the road at first. It is sometimes advantageous to cut the back slope vertical and to pay later for the soil that slips, while the earth is taking up its natural angle, as slip clearance is cheaper than excavation.

1	Number of chain.		
2	Distance in feet between chains at which cross-sections have been taken.		
3	Rate per cent. cubic feet dry masonry.		
4	Rate per cent. cubic feet lime masonry.		
5	Rate per running foot *pakka* parapet.		
6	Rate per running foot *kachcha* parapet.		
7	Rate per thousand cubic feet excavation.		
8	Rate per thousand cubic feet rock cutting.		
9	Rate per thousand cubic feet hard rock blasting.		
10	Front slope of hill side.		Earthwork.
11	Back slope adopted according to nature of soil.		Earthwork.
12	Sectional area of cutting according to Appendix I. or according to cross-section where country is flat.		Earthwork.
13	Cubic contents = column2 × 12.		Earthwork.
14	Cost = column 13 × 7 or 8 or 9.		
15	Height of wall.	Dry retaining wall.	Dry coursed rubble masonry.
16	Sectional area from Appendix I.	Dry retaining wall.	Dry coursed rubble masonry.
17	Length of wall.	Dry retaining wall.	Dry coursed rubble masonry.
18	Contents = column 16 × 17.	Dry retaining wall.	Dry coursed rubble masonry.
19	Height of wall.	Dry breast wall.	Dry coursed rubble masonry.
20	Sectional area from Appendix I.	Dry breast wall.	Dry coursed rubble masonry.
21	Length of wall.	Dry breast wall.	Dry coursed rubble masonry.
22	Contents = column 20 × 21.	Dry breast wall.	Dry coursed rubble masonry.
23	Cost = column (18 + 22) × 3.		Dry coursed rubble masonry.
24	Height of wall.	Retaining wall in lime.	Coursed rubble masonry in lime.
25	Sectional area from Appendix I.	Retaining wall in lime.	Coursed rubble masonry in lime.
26	Length of wall.	Retaining wall in lime.	Coursed rubble masonry in lime.
27	Contents = column 25 × 26.	Retaining wall in lime.	Coursed rubble masonry in lime.
28	Height of wall.	Breast wall in lime.	Coursed rubble masonry in lime.
29	Sectional area from Appendix I.	Breast wall in lime.	Coursed rubble masonry in lime.
30	Length of wall.	Breast wall in lime.	Coursed rubble masonry in lime.
31	Contents = column 29 × 30.	Breast wall in lime.	Coursed rubble masonry in lime.
32	Cost = column (27 + 31) × 4.		
33	Length of *pakka* parapet.		
34	Cost of *pakka* parapet = column 33 × 5.		
35	Length of *kachcha* parapet.		
36	Cost of *kachcha* parapet = column 35 × 6.		
37	Cost of 6″ coat of metal 12′ wide.		
38	Length of inner drain with edge stone.		
39	Rate of inner drain with edge stone per running foot.		
40	Cost of inner drain with edge stone = column 38 × 39.		
41	Length of inner drain without edge stone.		
42	Rate of inner drain without edge stone per running foot.		
43	Cost of inner drain without edge stone = column 4 × 42.		
44	Remarks.		

NOTE.—Wider columns would, of course, be used.

166. Methods of measuring up the work vary. A simple method is to use two thin well-stretched ropes, an end of one being fixed at the middle of the other, the junction being taken as a zero point from which the ropes are marked off in feet, every fifth foot being marked with blue cloth and every tenth foot with red. By moving about the ropes till AEB is a right angle and again till ABD is a right angle and noting the distances AE, EC, EB, AB, DB, it is possible to estimate the areas of the triangles ABC, ABD, CBD. If preferred, a rope and a 50-foot tape may be used or the areas of cross-sections can be calculated by noting the slope of the ground and the back slope of the excavation as also the width AB.

Fig. 42.



167. If the estimate has been recorded in such a form as the one given on page 72, it is possible to watch the expenditure chain by chain and to see if excesses are likely to occur or if savings are possible. The form looks puzzling at first sight, but on examination it will be found to contain just about what is required for a normal road, recorded in a systematic and methodical manner. Modifications of it will suggest themselves to officers who have road work to do.

168. The maintenance of a hill cart-road resembles that of a road on the plains, as far as attention to the road surface and drains and culverts are concerned, but larger road gangs may be wanted in places, for there is the road surface to be watered, where water is available, and as the traffic on a hill road is generally heavy, repairs have to be done quickly and slips cleared as soon as possible. For water-supply, it is necessary to build cisterns over a spring above the road and to convey the water through pipes to the road, where it may discharge through a masonry standpost into a long trough, where cattle and horses can drink and from which the overflow can be conveyed along the roadside drain and used for watering the road, the grass on parapet walls, etc.

169. Special care should be taken to see that all drains are kept clear and the waterway of culverts is not choked. It is usual to provide catchpits above road culverts to prevent the waterway, if it is at all restricted, getting blocked with stones and débris, and these should be cleared before the rains. The beds of streams should be watched to see that they do not cut back and endanger the foundations of bridges and any accumulation of water in the stream bed above a bridge, owing to landslips into the stream, should be noticed and dealt with, or there may be a lake-burst that will wash away a bridge and damage the road. Where an accident of this nature occurs, a temporary diversion of the road must be made and a temporary bridge put up as soon as possible.

170. Catch-water drains above a road and drains below a road should always be kept in working order, and the walls below a road which are intended to hold up slipping soil should be inspected from time to time and renewed, or repaired, as need arises. Slips of earth on to a road should be dealt with promptly by a breakdown gang, rocks blasted, and fallen trees removed, and the road surface made good.

171. All bridges should be examined at least once a year and iron bridges should be specially seen to and re-painted from time to time. Inspection houses should be kept in thoroughly good order and their surroundings should be kept in a sanitary condition, special attention being paid to the water-supply. The furniture and cooking utensils, lamps and crockery should be examined during road inspections and kept clean and fit for use.

172. As a rule, arboriculture is not much attended to on hill roads, but something can be done in places, where there are no forests, towards providing shade for travellers, and "*chir*," chestnut and walnut trees may be induced to grow along treeless stretches of road. As in the case of arboriculture on the plains, a programme of operations and much supervision are needed if systematic results are to be attained.

173. The following descriptive report of the estimate for the Chakrata hill cart-road from Kalsi on the Jumna in the Dehra Dun district to Chakrata is extracted from the College Manual on Roads, 7th Edition, and may be taken as a fair sample of a report on works of this class in the outer ranges of the Himalayas :—

The plains road is held to terminate, and the hill road to commence, at Kalsi. On the former the ruling gardient is 3 in 100, on the latter 5 in 100.

Description of country, lower section.—From Kalsi to Sahia, a distance measured on the line of 10½ miles, the road lies on the high lands, which form the western side of the Umlawa valley. These, in their lower features near the level of the river, abound in steep rocky ground and precipices, the river in many places passing through narrow gullies channelled out of the solid rock by the action of the water. At an elevation of 800 or 1,000 feet above the river's bed the ground is not so steep, and the surface is covered with soil and frequently under cultivation.

A line was laid out originally rising rapidly from Kalsi, until these comparatively flat grounds were reached and then carried along them.

This line, however, encountered a very serious landslip, in the 6th mile, which presented an obstacle insurmountable by any ordinary means. ~~This lies back in a valley~~ around which the line wound. The soil of loose shale slips from a height of about 500 feet above the line and over a length of about 1,000 feet. It was essential that this slip should be avoided altogether, which could only be done by crossing the gorge of the valley below it.

The only work of any importance whatever executed on this line was opening out a gallery in the precipices of the 3rd mile. There was, therefore, no need for hesitation in abandoning nearly the whole of the old line and adopting another, which should avoid the landslip, cut across the throat of the Dudhow valley, and present a gradually rising gradient and level portions, instead of a continuous rise followed by a fall.

The galleries in the precipices of the 3rd mile have been retained in the line, and doing this causes, in fact, the only difficulty with which we have to deal.

Zig-zag above Kalsi.—To preserve the ruling gradient, the line has to be carried back up the valley above Kalsi and to return, forming the only zig-zag that occurs in the whole line. The turn has been made as easy as possible on a flat table with a radius of 80 feet.

Gradients.—Above the precipices level portions have been inserted in every mile, alternating with gradients not steeper than 5 in 100 up to the 8th mile, from which point the line runs level to the crossing of the Umlawa. The Umlawa valley was said to be very malarious, and that it was considered essential to carry the line at a considerable height above the river. The line, as at present laid down, lies generally about 600 feet above the bed from the 2nd mile to Dudhow, from which point they gradually approach each other till at Sahia they coincide. In this upper part the valley expands very much and is free from jungle, and malaria need not be apprehended.

Why line was not carried to east of Umlawa.—It may be asked why the line was commenced on the west side of the Umlawa and not on the east, on which side Chakrata, the final terminus, lies. The valley of the Umlawa on its eastern side is exceedingly precipitous; it consists, in fact, of a single bold cliff rising abruptly to a height of about 1,000 feet from the river's bed, and extending for about five miles up its course, where it is broken by a ravine which discharges a water course into the river. It would have been impossible to cross this ravine, excepting at the level of its junction with the Umlawa, and at this elevation the whole road would have had to be cut out of the solid rock. The valley behind the ravine to the east does not extend in the direction in which the line has to be carried; a long detour would have been necessary through Pokri, and the road would probably have been 35 miles long instead of 25.

Large bridges.—There are but two works of any magnitude on the lower part of this section, that is up to Sahia, *viz.*, the landslip bridge in the 6th and the Umlawa bridge in the 10th mile. The former consists of a single span of 50 feet, a circular segment of 120° crossing the neck of what we have termed the landslip valley.

In selecting the position for the bridge, it was necessary to keep entirely clear of, and below, the landslip, and at the same time not to go much below, as the lower the line the more rocky and precipitous the ground. The rock on either side is not of the nature to afford secure foundations of itself. It is rather shaly and friable. The bed of the stream is formed partly of this shale and partly of large rocks and boulders fallen from above. The bridge spans the throat of the valley; it is much larger than it is required to pass the water. but it is necessary to throw back the abutments in order that they may not be injured by the larger masses of stone brought down. It is also very questionable whether a reduction in the span, which would involve much increased work in wing-walls, etc., would be economical

Umlawa bridge.—The Umlawa river rises in the Deobund range, about 10 miles above the point at which we cross it. This point was selected with special regard to advantage of position for forming the bridge, bounded in a measure by the limits within which it was necessary to commence the ascent towards Chakrata. The river collects the whole of the rainfall of the western side of the Chakrata, Pokri and Bairat spurs, of the eastern side of the Naga spur, and of the southern slopes of Deobund lying between them. There is a considerable perennial flow of water in the river easily fordable in the dry seasons, increasing during rain to a perfectly impassable torrent. In the course of about 18 hours after the cessation of heavy rain it subsides and becomes fordable with some difficulty. The fall in the bed between Sahia and Kalsi is 1,700 feet in a length of bed of nine miles about; from Dudhow downwards it is steeper than from Sahia to Dudhow, indeed in the lower portions it falls in a succession of cascades. The fall in the bed, as measured for one mile above the crossing, is about 150 feet per mile.

The water channel at Sahia is well defined; the valley has expanded and has a moderately level bottom, the river having channelled out a course for itself, and the ground rising from it on either side in cultivated terraces partly of artificial formation.

When the river is in flood, the force of the water is very great, carrying large masses of stone before it. I think it, therefore, expedient not to place a pier in the bed subject to rude shocks, but rather to span the channel by a single arch of 60 feet.

Good building stone abounds in the neighbourhood, and although, for an arch of this size, it will be necessary to prepare voussoirs of dressed ashlar, the cost will not, I think, appear extravagant.

In this case the left abutment can be placed securely in a solid mass of rock which projects from the bank, and the position of which formed a chief feature in inducing the selection of this crossing. The force of the current is directed towards this side. The stream will pass as directly through the bridge as can be hoped for in the short reaches of a river of which the course is so tortuous.

Line above Sahia.—The character of the ground over which the line of road runs above Sahia is very different from that below. The slopes are generally easy, and comparatively but little rocky ground is met with. The distance along the road from Sahia to where the line cuts the ridge at the depôt is 15 miles.

Sainjh valley bridge.—As at first laid down, the line entered a valley below Sainjh, in which it ran back for nearly a mile; the throat of this valley is formed by two abruptly projecting rocks, separated by an interval of between 60 and 70 feet, and enclosing a chasm 70 feet in depth. It was decided that this chasm should be spanned either by an iron girder or stone arch and the long detour around the valley be saved.

There is nothing else on this upper section on which it appears necessary to offer special remarks.

Marches for troops.—Troops proceeding to the sanatorium will probably have to make two marches from Kalsi to Chakrata. The distance by the cart-road is 25½ miles from the lower encampment at Kalsi to the point at which the line strikes the ridge near the depôt; the site for the regiment is about one mile further on. Whilst the carriage must of necessity follow the cart-road, the men might march partly by this road and partly by paths of steeper gradient that may be constructed to cut off some of the long detours.

The most favourable place for an intermediate encampment is Sahia at the Umlawa bridge; here there is moderately flat ground and an ample supply of good water from the river. The lower section of 10½ miles cannot be shortened by the expedient above named, but the upper section of 15 miles may probably be reduced by paths on a gradient of 10 in 100 to 13 miles. These paths may be opened at a very small expense, probably not more than Rs. 500 per mile, as the features and soil on the upper section are favourable.

Water.—Water is found at intervals all along the line, but in abundance only at the landslip, Dudhow, the Umlawa, Korwa, and at the streams in 10 and 11 miles of upper section.

Surveys.—The surveys and estimate have been prepared with the utmost care. After the line had been flagged out, it was repeatedly examined and corrected, where necessary, to secure the best points at which to cross the watercourses, or to avoid difficult ground without falling into other errors or difficulties. A pathway was then cut, on which the levels were taken and a traversed line surveyed; a cross-section was taken every 100 feet, and these have been plotted on the plans in contour lines at vertical intervals of 50 feet. The nature of the soil was ascertained in each 100 feet, and has been exhibited by different shades of colour on the drawing. Permanent bench-marks have been set up at frequent intervals. The centre line of every culvert has been marked by strong pickets.

Estimates—Excavations.—The quantities of excavation have been taken out mile by mile for every 100 feet on a tabular form, classifying the work under the three headings of rock, stony and soil. The specifications of which are stated to be—

Rock—that which can be removed only by blasting and the crow-bar.

Stony—soil freely intermixed with stones of such nature that the combined use of crow-bar and pickaxe is necessary for its removal.

Soil—that which can be removed by the *phaora*.

Culverts.—The culverts have been arranged under the standard spans of 2½, 5, 7½, 10 and 15 feet; any opening of larger size is classed as a bridge. The quantities of work in culverts are taken out mile by mile according to the standard drawings, allowance being made for extra work in those of which the piers are higher than provided in the standard.

Width of road.—A 15-foot width of roadway clear has been given to the culverts, one foot more than has been allowed in galleries cut in precipices. The width of road in the several portions have already been fixed by Government.

Scuppers.—The small openings for discharge of road drainage 18″ × 18″ have been termed scuppers; they have been provided in the proportion of from 15 to 40 in the mile of road according to the nature of the ground. The position of each scupper has been determined after a careful consideration of the features of the ground, the nature of the soil, gradient of road and extent of hill slope below which it occurs. It may possibly be necessary to add to their number. It is difficult to determine this until the road has been opened to its full width. The scuppers are taken out by the mile in the estimate.

Parapet walling.—The parapet walling is estimated mile by mile, divided into dry stone and in mortar. The dimensions and nature of the walling have been discussed in previous correspondence. An opening of one foot is left at each culvert, and one of three feet at every 500 feet, to permit of cattle passing to graze on the hillside.

Metalling.—Metalling has been provided to the full width of the road and thickness of six inches.

Compensation for land.—Compensation will have to be given for a very small amount of cultivated land in th bed of the Umlawa and at the villages of Sainjh and Korwa. The whole of the rest of the line runs over waste ground.

Rates—Total cost and cost per mile.—The rates have been determined by the experience already gained in opening out pathways and forming galleries in the precipices above Sahia. The total cost per mile of the line, Rs. 13,628, does not appear high by comparison with the cost of the Naini Tal road.

On the other hand, I do not think that we have erred on the side of too great economy; the principal outlay is in excavation, the rates of which are based on the experience already gained.

Method of calculating excavations.—It is to be observed that in ground of this nature, it is impossible to estimate the quantity of cutting with the accuracy attainable on ordinary

roads, nor is it easy to foresee precisely where it may be necessary to substitute retaining walls of earthen slopes above the road. The calculations have been based on the following considerations. Where the natural slope of the hillside has a base of 2 to 1 perpendicular, the soil is generally not tenacious, and frequently the dip of the strata will be with the slope; in this case we have assumed that the back slope may be left at 45° or base = perpendicular.

Where the natural slope has a base of 1½ to 1 perpendicular, the conditions point to the conclusion that the soil is tenacious, or that the strata lie nearly horizontally, and here we assume for the back slope a base of ½ to 1 perpendicular. It is in these places that we may most probably have to add retaining walls, as, where there are any symptoms of failure in soil, it would be more economical to build a breast wall than to add to the cutting by the very large area that would have to be taken out in section to secure a back slope that would suit the soil. In these cases the sectional area of cutting saved by the breast wall will probably nearly compensate for its cost.

Where the natural slope is 45°, or steeper, there is evidence from this fact that the soil must be very tenacious, that it is on rock, or that the dip of the strata is opposed to the slope. In these cases we have assumed sections varying, in the back slope, from ¼ to 1 to a vertical wall.

Pattern cross-sections of excavation.—Nine pattern cross-sections have been plotted on these principles, the areas of which are applied in the table of quantities to each successive 100 feet, according to the local natural slope ascertained, as I have above said, by measurement on the ground.

I do not see how we could arrive at an estimate of the quantities likely to be much nearer the truth, until by opening perhaps half the width we can ascertain the exact nature of the soil at every point. It may, perhaps, be accepted as sufficient to promise that on the work reaching this stage, the table of quantities shall be revised with a view to determining whether the gross quantities provided will cover the cost of the completed work.

The quantities and cost of all the other descriptions of work can, of course, be arrived at very closely, and exception within a moderate limit being allowed in the case of the scuppers, to the number of which some addition may, in certain places, be necessary.

CHAPTER VII.

COLLECTION AND CONSOLIDATION OF KANKAR.

174. Kankar is a form of limestone which is found in layers at various depths below ground, very often in land impregnated with saltpetre or "*reh*" and known as "*usar*" land in the United Provinces. The thickness of the beds varies. Often the kankar is found in very hard layers and has to be broken into blocks. This is known as block kankar or "chatt" or "silia." It can be used for building purposes, or for pitching, and, when broken to a 2-inch or 1½-inch size, for road work. It is often very hard and has to be consolidated, as stone is consolidated, that is, with the addition of binding material as the work nears completion. The nodular form of kankar is called "*bichua*." It may be found in clay soil or in sandy soil, its quality as road material varying with the nature of the soil. That found in "*usar*" is generally white and soft, while sandy clay produces weaker kankar than is obtained from clay soils. Sometimes it will be found that a quarry yields stuff that looks good, but that breaks up into very very small pieces which do not make a good road. Occasionally nodules will be found above the soil in ravines. These are clean and hard, but difficult to consolidate and make an indifferent road.

175. Good lime, sometimes rich, sometimes hydraulic, can be made from kankar, but the best road kankar does not make the best lime, nor does the best lime-producing kankar make the best material for road work. Good kankar for road work should be heavy and hard, and dark in colour when fractured. Most quarries, especially of block kankar, will produce some that is of poor quality, breaking easily, crushing to powder, unfit for road work, and this will be carted to the roadsides as will also a quantity of earth, unless measures are taken to see that "cleaning" is done at quarry.

176. Quarries will generally be found on private land, and landowners or zamindars will often object to their being worked, but in the United Provinces, it is recognized that the Government owns the kankar and can have it on payment of a royalty of four annas per hundred cubic feet as compensation for the disturbance of the land. Failing agreement on these lines acquisition of the land under the Land Acquisition Act becomes necessary. In some districts neighbouring landlords try to impose a fee as compensation for damage done to their crops by dust raised by passing carts loaded with kankar, but this should not be allowed.

177. The men who dig kankar are paid in different ways in different districts. Sometimes they are paid a daily wage ; at other places they receive payment according to the work they do. The quantity of kankar they can dig depends on the quality and on the depth at which the layers are found. Taking the daily task at 15 cubic feet and the daily wage at 4 annas, the cost of 100 cubic feet of metal is roughly Rs. 1-12, and if the task is 12 cubic feet, the cost is approximately Rs. 2. This is for digging, breaking and cleaning at the quarry. In addition 4 annas have to be paid as land compensation for every 100 cubic feet and 8 annas for further breaking and cleaning, and for stacking at the roadside. The rate for the metal stacked at the roadside exclusive of carriage would, therefore, be about Rs. 2-8 to Rs. 2-12 per 100 cubic feet, but might be less or more according to the task and the labour rate.

178. In estimating what the task should be, due consideration should be given to the quantity of inferior metal that a quarry produces, for sometimes nearly all that is dug can be used, and sometimes 20 per cent. may have to be put aside. In one district a contractor paid eight annas for a "*paimana*" of 30 cubic feet, which reduced to 22 cubic feet when cleaned, so the rate became Rs. 3 per 100 cubic feet, including four annas for royalty and eight annas for cleaning, breaking and stacking. In another case six heaps of 13 cubic feet cost Re. 1, and the waste was 10 per cent., making the rate, after adding 12 annas as above, Rs. 2-2-6 per 100 cubic feet. Officers who prepare rate lists need to collect information of this kind and in as great detail as possible.

179. The two examples given below are taken from notes of work done in different places :—

(*a*) Five men, at 4 annas each, dig 10 feet by 10 feet by 5 feet, and produce 70 cubic feet of metal, which they clean and which reduces to 60 cubic feet.

		Rs.	a.	p.
∴ 100 cubic feet cost,	... ...	2	1	0
Land compensation,	... ...	0	4	0
Break, clean, stack	... ...	0	8	0
Total cost of 100 cubic feet, exclusive of carriage,	...	2	13	0

(*b*) Kankar layer is 12 inches deep and three feet below ground. For 100 cubic feet of kankar an area of 134 sup. feet is dug out.

		Rs.
Earthwork 134 × 3 at Rs. 2 per thousand,...	... ...	= ·800
Kankar 134 × 1 at Rs. 4 per thousand, ...	... ...	= ·536
~~Break and~~ separate 134 at 6 annas per cent.,..	....	= ·500
Clean, break ~~and~~ stack 100 at 10 annas per cent.,	... ...	= ·625
Royalty or land compensation,.....	....	= ·250
Total for 100 cubic feet,	...	2·[illegible]
Exclusive of carriage, say Rs.,	...	2-[illegible]-0

180. Carriage is sometimes paid for at a rate of eight annas per hundred cubic foot per mile, estimated, probably, on a daily task of 25 cubic feet carried 16 miles at a rate of one rupee per cart for a day.

Thus for N miles—

Number of estimated trips, ... $= \frac{16}{2N}$

Quantity delivered at a cost of 16 annas, ... $= \frac{16 \times 25}{2\ N}$

$\therefore$ 100 cubic feet cost, ... $\frac{100 \times 2N \times 16}{16 \times 25}$ or 8N annas.

which is 8 annas per mile.

181. For short journeys the rate per mile should be higher than for a long lead. It is difficult to find a rate that will suit most cases. To find a rate that will suit all is impossible, for what suits one road will not suit another where the villages along a road, and near it, in which perhaps the cartmen live, or halt, during journeys, are differently placed, or where, again, a stretch of very sandy soil has to be crossed in one case and not in another, or a stream to be negotiated, and it will sometimes be found that there will be a rush of contractors for some miles of collection, while none will tender for others. In a case like this an officer who frequently inspects quarries and makes himself well acquainted with every circumstance connected with them will be able to say why this is so and will get the rates adjusted.

182. The rates for carriage given below are based on the assumption that a cart costs 14 annas a day and can carry 25 cubic feet to 30 cubic feet of metal. The quantities that can be delivered by each cart daily may be taken as 100 cubic feet for the first mile, 55 cubic feet for the second, 40 cubic feet for the third and 32 cubic feet for the fourth mile. These are not absolute figures, for they will vary with circumstances. They are based on four trips, two trips and one and-a-half trips for miles 1, 2 and 3 respectively.

Then the carriage rates will be for 100 cubic feet—

Mile.	Rs.	a.	p.	
1, ...	0	14	0	
2, ...	1	10	0	or 12 annas more.
3, ...	2	4	0	or 10 annas more than for 2.
4, ...	2	12	0	or 8 annas more than for 3.

For mile 5 and subsequent miles add 6 annas per mile per 100 cubic feet.

183. The rates for carriage will, therefore, be as given in the table below ;—

TABLE VI.

Kankar collection.—Carriage rate for 100 cubic feet.

Mile.	Cost.	Rate per mile.	Mile.	Cost.	Rate per mile.
	Rs. a. p.	Rs. a. p.		Rs. a. p.	Rs. a. p.
1	0 14 0	0 14 0	11	5 6 0	0 7 10
2	1 10 0	0 15 0	12	5 12 0	0 7 8
3	2 4 0	0 12 0	13	6 2 0	0 7 6
4	2 12 0	0 11 0	14	6 8 0	0 7 5
5	3 2 0	0 10 0	15	6 14 0	0 7 4
6	3 8 0	0 9 4	16	7 4 0	0 7 3
7	3 14 0	0 8 10	17	7 10 0	0 7 2
8	4 4 0	0 8 6	18	8 0 0	0 7 1
9	4 10 0	0 8 3	19	8 6 0	0 7 1
10	5 0 0	0 8 0	20	8 12 0	0 7 0

Mile 20. In this case about two and-a-half days are required for one trip, so 25 cubic feet will cost Rs. 2-3 and 100 cubic feet cost Rs. 8-12.

Mile 15. About two days must be allowed for one trip, so 25 cubic feet cost Rs. 1-12 and 100 cubic feet cost about Rs. 7.

Mile 10. Allowing one and-a-half days per trip, the cost of 25 cubic feet is Rs. 1-5 and 100 cubic feet would cost about Rs. 5-4.

The results in the table agree fairly well with these results.

184. Extreme accuracy is not required in fixing rates. What is wanted is a fair rate list against which contractors can tender in competition with others.

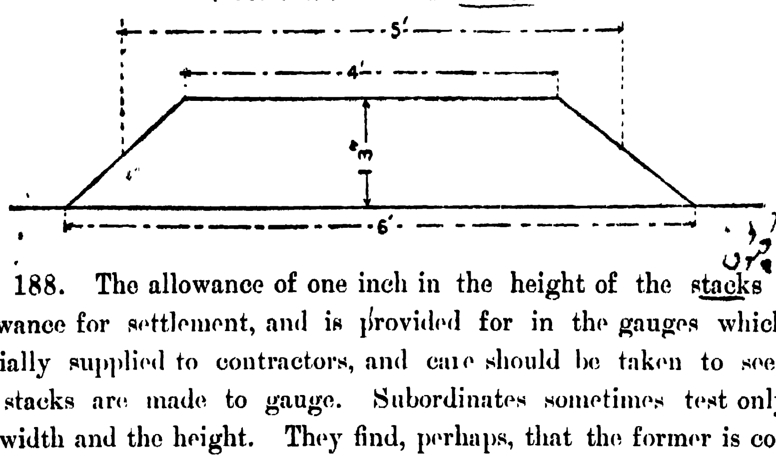
185. The rate for road metal delivered on the road will be the sum of the items digging, cleaning, breaking, stacking, carriage.

186. Sometimes kankar has to be carried by both road and rail or by road and canal or by all three. In these cases detailed calculations have to be made based upon the most favourable rates at which the Railway Company concerned or the Irrigation Department will carry road ballast. Terminal charges and loss in handling should always be taken into consideration.

187. When the kankar is brought to the roadside, it should not be thrown down in the place where it has to be stacked, but, as a rule, on the opposite side of the road, but not on the travelling surface, and there it ought to be spread out to dry, then well dusted and broken to the proper size, any soft stuff that it may contain being removed before it is carried across the road to be stacked. Small stuff should also be removed and piled in regular heaps away from the road metal. The stacks should not be made on the travelling surface of the road, if this can be avoided. They are made 13 inches high (measured as 12 inches) and of a section corresponding to that of the road, for instance, a road 16 feet wide for which a $4\frac{1}{2}$-inch coat is being collected would have stacks of an area of $16 \times \frac{3}{8} = 6$ sup. feet and a road 12 feet wide would have a stack of area $12 \times \frac{3}{8} = 4\frac{1}{2}$ sup. feet. For petty repairs metal stacks may be five S. F. in section, as this is a convenient figure for calculations.

Fig. 43.

Cross section of 5 foot stack of metal



188. The allowance of one inch in the height of the stacks is an allowance for settlement, and is provided for in the gauges which are officially supplied to contractors, and care should be taken to see that the stacks are made to gauge. Subordinates sometimes test only the top width and the height. They find, perhaps, that the former is correct, as for example, four feet in the case of a stack that is supposed to be of five superficial feet, but the height is less than it ought to be, say, for instance, nine inches instead of 13 inches. They post up their measurements as $\frac{4+6}{2} + \frac{9}{13}$ or as $5 \times \frac{9}{13} = 3{\cdot}46$ superficial feet, but this is not correct, for the average width of the stack is less than five feet. It is practically four and three-quarter feet. Kankar stacks should be measured soon after they are made, for if this is not done, it is difficult to decide what were the measurements of the original stacks.

189. Stacks should be opened out at varying intervals, front and back, for examination. Very often some large kankar, some small kankar, some soft kankar, some dirty kankar will be found in them and occassionally the inspecting officer may find a core of earth or a

large rock. He may find the stacks placed on high ground sloping away in both directions which reduces the height at the centre, while giving an appearance of full height, or they may be concave at top while of full height at the edges, especially when wide stacks are used, as they have to be where stacking space is limited. If the berms are levelled before stacking is started mistakes of this kind are avoided.

190. Collection of kankar begins soon after the end of the monsoon. It is sometimes delayed on any plausible excuse, and an attempt is made in March to rush in as much as possible before the end of the financial year, in the hope that inferior stuff will be passed in order that funds may not lapse. Endeavour should be made to prevent this in arranging contracts by seeing that the work is not given to men of straw and, subsequently, by seeing that progress is made in accordance with the contracts. There are times of the year when, owing to agricultural needs, it is extremely difficult to arrange for carriage; but if the work of collection is started early and steady progress is made at first, there need be no rush in March.

191. It is a good plan to get permission to start collection in a few miles that do not appear in the current estimates, but will certainly appear in the estimates of the coming year, for, if contractors fail in collecting any portion of the miles that are in the sanctioned estimate, payment can be made for work done on the extra miles. After March any miles that are incomplete can be completed by June and any new work undertaken that can undoubtedly be finished by June. If too much is attempted there will be some incomplete collection in June, or the work will be hurried and inferior metal will be brought on to the road.

192. As an alternative it is well, when framing a programme of work in April, to divide this into miles of collection called A, B, C. A miles mean those that are to be consolidated during the coming monsoon, B miles are those that should be collected between the end of the monsoon and the end of the following March, and C miles are a few extra miles that form a reserve on which payments can be made if any B miles remain unfinished. Miles of the B and C class which are incomplete at the end of March become A miles of the next year. The miles classed as A and B are covered by the grant for the year and the value of the collection provided under C may equal 25 per cent. of the grant. There is thus a reserve which meets deficient collection on B miles, or admits of further payments if all B miles are collected and further allotments are made. Without some such arrangements as those indicated above, contractors may collect indifferent material in March in the hope that it will be paid for merely to prevent funds lapsing on the 31st March.

193. Specifications for kankar collection seldom say more than that "the metal is to be hard, clean and fit for road metal in every respect, broken to a 1½-inch gauge, sieved and cleaned, so as to be perfectly free from earth and other matters before it is brought to the roadside." This evidently implies that each piece should be of the size specified, as far as possible, and that "*bajri*" should be screened out, and there is no doubt that uniformity in size, as in quality, is to be aimed at. It is recognized, however, that uniformity cannot always be secured for specifications for consolidation, say "the new metal will be packed by hand, the largest sized metal being spread in the lowest layer, with the medium sized metal above this and the small on top."

194. If the metal is broken from blocks there is not much danger of there being too much collected of smaller size than that specified, but with nodules there is always a chance of too much of the stuff smaller than one and-a-half inches finding its way into the stack, and it would be as well to limit this; but a good deal depends on the sort of kankar a quarry produces and, no absolute percentage can be prescribed. (The Road Board in England allow 15 per cent. of stuff under one and-a-half inches in their specification for 2-inch stone). Stuff over the specified size should not be collected.

195. Though the consolidation of kankar is sometimes done by means of steam-rollers, and though some hard clean block kankar would be better consolidated by steam-rollers than by rammers, it is usual to employ the latter and they undoubtedly help to make a better road with ordinary kankar than steam-rollers would, for rollers would crush the material.

196. When there is enough water on the roadside during the monsoon for the work of consolidation to be done, the roadside stacks of metal should be opened out, and the metal should be spread out, so that it may dry to some extent and attain a state in which it can be cleared of the dirt which is to be found in all stacks of kankar after they have been standing for some time, even though this may have been cleaned at the quarry, and again at the roadside, before being stacked. The presence of this dirt is due to the dust that blows about in the dry season, settles into the stacks and cakes when rain falls on them. Opening out the kankar heaps lets the wet material dry if there is clear sunshiny weather, or lets it be washed off by heavy rain. Failing effective cleaning in this way, the metal, before being laid on the road, should be put into baskets and dipped into water. At this time, too, any large pieces of metal that have been overlooked during stacking should be broken to a size of two inches. At the same time the contractor should collect at the

site of the work such rammers (*durmats*), templates (*pharmas*), digging tools (*phaurahs*), picks (*kudals*), pick-axes (*gaintis*), rakes, twine, flags, lanterns, hammers, wooden barriers, baskets and gharas for water as are required for the work. It this is not done there will be delay later on and the labour gangs will be idle while a man is sent to the central depôt to get tools.

197. When the work is being started, a barrier should be erected at each end, at a distance of 20 feet from the portion in hand, and a red flag should be placed conspicuously at each barrier by day and two red lights by night. Similar flags and lights should be placed at cross-roads. Notice-boards (Appendix 4) for the guidance of motorists should be put up at about 275 yards from the portion of the road under operation. The earthen sides, or patris, of the road should be kept free of tools, or other obstructions, and in thorough repair for the use of traffic all the time the work is in hand.

198. If the road is a new road under construction, the earthen bank will need to be shaped and rolled, or beaten firm, to receive the lowest coat of metal, in cases where a foundation of large stuff is not being used. Some officers like to make their embankments up to the full formation level and to cut out a channel about six inches deep to receive the road metal. Others make the road bank somewhat lower than the finished formation level and beat down the centre 12 feet of the road bank with rammers, shaping it to correspond to the finished surface of road metal. In this case the patris or shoulders of the road are made when the consolidation is finished. Both methods are used. The latter seems to be the better.

199. If the road is an old road which is having a renewal coat put on it, the next step will depend on whether it is being renewed with a 4½-inch coat, or re-surfaced with a 3-inch coat. And it should be said that these terms are used here in the sense in which they are used in the United Provinces, for sometimes, in road literature, re-surfacing is used to denote what in the provinces referred to is called renewal, *i.e.*, a new 4½-inch coat laid on the old surface after this has been lightly scarified.

200. If the road is being renewed with a 4½-inch coat, the old surface will be very lightly scarified all over, just to roughen the surface, without destroying what is the foundation of the new coat. If the road is being re-surfaced with a 3-inch coat, the old surface will be dug up all over, to a depth of one and-a-half inches, the loosened stuff will be sorted out to separate from the rest such material as is fit to be used again, and the serviceable material will be mixed with the newly-collected kankar

before the metal is laid on the road surface. Both methods are used. The former is the better of the two, but sometimes the smaller initial cost of the latter prevails. It is not necessary in the case of re-surfacing to repair the old road surface as it will be dug up, but in the case of a renewal coat, the old surface should be patched before it is scarified. Some officers cease repairing a mile of road on which collection for renewal is in progress—a system that cannot be recommended; for the surface which is not repaired will deteriorate rapidly and will not make a sound bed for the new coat.

201. While the scarifying is in progress on an old road, and before the metal is spread on a new road, a wall of clay 8 inches wide by 6 inches high should be aligned, with the aid of flags and twine, on each side of the road metalling, the distance between the two parallel walls being determined by the width of the road metalling. The construction of these walls should, in the former case, keep pace with the scarifying. In both cases they should be of the best clay obtainable, and well puddled, for they are intended to prevent the new metal from spreading when being consolidated and walls of dry loose soil are ineffective.

202. Just inside these walls the old road metal should be nicked to a width of about 2 inches and a depth of 3 inches to give the edges of the new metal a hold. To make these nicks heavy pick-axes are used, but they should not be used for scarifying the road. For this purpose light 6-inch picks, with an 18-inch handle, should be provided, and the coolies should sit and use them so that they cannot scarify the surface to a greater depth than is required to roughen it. Some officers like to dig up the old surface, allowing for this purpose the use of heavy pick-axes wielded by professional diggers working while standing up. This method breaks up the road and produces mud that works up through the new metal while it is being consolidated and, at the same time, reduces the effective thickness of the road. It is not recommended, except when re-surfacing has to be done. Other officers prefer to mark, or score, the road with diagonal patterns of nicks some 2 inches deep at intervals of 2 feet. Observation has shown that kankar roads renewed in this way wear in a peculiar manner, ridges being left where the diagonal nicks have been made, while the intervals between the ridges are worn down to the old surface. This does not always happen, but is very noticeable at times, and as the object of renewing the road is to secure a compact and even wearing surface, this method of diagonal lines cannot be recommended, nor can the use of small craters, at intervals of a yard apart, such as are produced by striking the surface here and there with the point of a pick-axe, nor again can a method

that was once in fashion, which is, to brush the old surface and lay the new metal on it. The two never join properly and occasionally the upper coat comes away in large pieces after a few months.

203. When a length of 200 feet has been scarified, the operation of spreading the metal should begin. The metal from the spread-out stacks should be raked up into baskets, and not dragged into them by means of "*phaurahs.*" It should then, if this is necessary, be dipped in water to wash off superfluous dirt and be thrown on the road surface in front of the packers who proceed to sort the kankar and hand-pack it, with the larger stuff below and the smaller stuff above, arranging it all in a skilful way and according to the templates or "*pharmas*" provided for the work, and using light hammers where necessary. This packing of the road metal is of importance and care and attention should be given to its being properly done. The templates should be placed at 16-foot intervals and carefully levelled, so that they may indicate the true surface of the road. Sometimes cubes of wood of the right dimensions are used as gauges, one at the centre, one at the middle of each side, and one at each edge.

204. As the packing proceeds so the construction of the clay walls and the scarifying of the road surface proceed ahead of it. When 200 feet of the packing has been done, consolidation is begun. These figures are given on the basis of about 900 cubic feet of work being finished, in all respects, every day, or 200 running feet of a 12-foot road having a 4½-inch coat. There will thus be 600 feet under operation on the third day, and if the work proceeds satisfactorily, the operations of scarifying, spreading and consolidation will not overlap, nor will the former get ahead unless the consolidation drags. Nor more than 660 feet should be under operation at any time.

205. Plenty of water is needed for the consolidation, and for good work the number of rammers should never fall below 12 for a 9-foot road and 16 for a 12-foot road. Whenever possible, all the men should be experienced in this work, but if this is not possible, some should be so and the others should be taught. The gang of 16 men should, first of all, proceed to ram the edges of the new metal to a width of about two feet, and for this purpose they should divide into two lots of eight men and stand with their backs to the middle of the road, moving sideways up and down a short length of the road, and thoroughly consolidating the margins of the coat of metal. There will be plenty of water here if the bhisties and coolies fetching water have poured enough over the surface of the road, for it will flow down to the

edges and be held up by the marginal walls of clay. and the gangs will be well plashed and will try to shirk ramming hard enough. As soon as the edges have been sufficiently consolidated, the gangs should form two lines across the road at right angles to the previous position and work up and down the portion of which the edges are nearly done and should ram both edges and centre and beat down the marginal clay walls, which should not be cut down by means of "*phaurahs*." The partial consolidation of the edges before the centre is touched prevents the centre being beaten down flat, the edges and the clay walls form a support to the central metal and keep it from spreading and settling, which it will probably do if the edges are not rammed first. It also (aided by the 3-inch nick referred to above) prevents the breaking up of the edges that is to be seen on roads on which the margins are insufficiently consolidated.

206. No "binding" or "blinding" is required for ordinary kankar roads, but some qualities of kankar require the after addition of some kankar "*bajri*" to finish off with, after the metal has been thoroughly rammed; and it is found necessary, very occasionally, to finish off by pouring liquid clay over the consolidated surface. Top dressings of any suitable kind need not be objected to, provided the road metal has been thoroughly rammed before the dressing is put on. None should be allowed to be added at the discretion of a contractor. He should always take the orders of the engineer on this point. From time to time during consolidation, the top surface of the road should be tested by means of a shaped template, made to slope at 1 in 36 from the centre to the edges, to see that it is being finished to the correct camber. All mud should be washed off and the surface should be firm and open and not a mixture of clay and kankar on which every wheel makes an impression.

207. When the day's work is done two lanterns should be placed at each of the barriers. The best form of lantern is a large box, with red cloth face and sides, in which a light is kept burning. Small hand-lanterns are of no use. They give no light and their faces soon get covered with a smoky deposit. Very effective lights are required, because motorists will not be able to see the special motor warning, and they need something more than a dim red lamp to give them warning that the road is up.

208. As soon as the consolidation is finished and the road is thrown open for traffic, work on the "*patris*" should be started. These should be finished off at a slope of 1 in 36 outwards in continuation of the slope of the road surface. There will, sometimes, be difficulty in getting earth from the side drains, and occasionally it may be absolutely necessary to

defer the execution of part of the work for a time, but, as a rule, it can be done as soon as the consolidation is finished. If this is impracticable. a strip of "*patri*" two feet wide adjoining the edges of the metal can be made up as soon as the adjacent portion of the road is opened to traffic, and the rest can be completed later.

209. All holes and channels in the slopes of embankments should be filled in, the earth being well beaten down and dressed off neatly. All clods in the "*patris*" should be broken and the surface should be rammed and smoothly dressed. A template, twine and pegs, or flags, will be required for this work, which should be neatly done. Excavation for the earth that is required should be made in the ditches at the road boundary which should be dug evenly in the direction of their length, the 5-foot cross-bars between 50-foot borrow-pits, where these exist, being left undisturbed ; but the formation of such borrow-pits should be avoided altogether in the neighbourhood of inhabited areas, where no excavation should be made that cannot be drained. No earth should be dug whithin five feet of a tree. milestone, furlong post, or boundary pillar, or any masonry work.

210. When traffic is allowed on the newly-consolidated portion of a road, great care must be taken to keep it spread over the road, for if it keeps on one track, ruts will certainly form. This diversion of traffic should, when necessary, be caused by spreading a little fine "*bajri*" in the places where the ruts show signs of forming and by brushing the road surface from time to time. *See* also paragraph 259.

211. The cost of kankar consolidation depends on the price of labour and on the distance water has to be brought. For ordinary work it will be somewhat as follows :—

Consolidation of cubic feet daily—	Rs.	a.	p.
4 beldars at 3 annas scarifying surface, ...	0	12	0
2 bhisties at 3¼ annas making clay walls, ...	0	6	6
4 beldars at 3 ditto, ...	0	12	0
1 coolie at 1½ ditto, ...	0	1	6
2 beldars at 3¼ annas carrying and spreading, ...	0	6	6
6 coolies at 2½ ditto, ...	0	15	0
5 coolies at 2 ditto, ...	0	10	0
2 mates at 6 annas ramming, ...	0	12	0
16 beldars at 3¼ annas do., ...	3	4	0
6 bhisties at 3¼ annas, ...	1	3	6
4 chaukidars at 3 annas, ...	0	12	0
Kerosine oil, etc., ...	1	5	0
Total for 900 cubic feet, ...	11	4	0
Rate for 100 cubic feet, ...	1	4	0

Nine hundred cubic feet represent 200 feet of a 12-foot road with a coat of metal four and-a-half inches thick.

212. The renewal of "*patris*" is generally estimated at Rs. 40 per mile which, if the earthwork is taken at Rs. 4 a thousand cubic feet as an all over rate, including dressing and patching, represents 10,000 cubic feet per mile or 5,000 cubic feet for each "*patri*," a larger figure than is necessary in most cases, now that roads are made with a proper slope of 1 in 36 for drainage instead of having their earthen shoulders or "*patris*" brought up level with the road metal—a system that choked the surface drainage and ruined the road. It would probably be sufficient to allow Rs. 20 or Rs. 25 per mile where "*patris*" are to be renewed in connection with a 4½-inch renewal cost; but no provision for this work is necessary in the case of a new road, for the item "Earthwork" should include all that is necessary.

CHAPTER VIII.

STONE COLLECTION AND CONSOLIDATION.

213. Stone may be obtained from regular quarries worked by Government or by contractors as in Bundelkhand, or near Agra, or Mirzapur, in the United Provinces, or from the beds of mountain torrents where boulders are to be found, as at Hardwar, or from places in the hills where limestone can be obtained, as on the road up to Naini Tal. These limestone blocks are usually taken from the bed of a stream near the road and broken on the road side, and the road metal thus obtained makes an excellent road for light traffic. River boulders of quartzite or sandstone do not break into such good metal as limestone yields. The boulders are round and smooth, and are not always to be had of large size, and one surface of nearly every bit of broken stone is smooth and rounded and difficult to consolidate. Boulders which are intended for road metal need to be carefully chosen and small ones should not be taken where those of larger size are obtainable.

214. The regular stone quarries of Mirzapur usually produce sandstone, but there are in Bundelkhand a few granite quarries that promise well. In some parts of India trap is obtainable. This is recognized as being the best for stones for road work for trap, which includes basalts and whinstone, is very compact and elastic has a high resistance to crushing without being brittle, and its dust usually has good cementing properties. Granites follow as next in value. They vary greatly and, as a rule, are not very excellent road stones, for the quartz and felspar in them are brittle and the latter is easily decomposed, producing sand and clay. Granites without mica offer great resistance to wear and those which are free from quartz are the best for road work. These go by the name of syenite. Limestones are usually deficient in hardness and toughness, but possess cementing power. Those which are not crystalline are the best for road work. Crystalline limestones are not always satisfactory. Sandstones are, as a rule, unsatisfactory, for they are easily pulverized and have but little cementing power. Quartzite rocks, though useful sometimes, are often as bad as sandstone. They were originally sand, changed into a compact mass by pressure. Quartz when found in large veins sometimes makes a fair road metal, for it is hard and breaks with sharp edges; but it readily crushes into powder, being brittle, and has no binding power.

215. Whatever may be the disqualifications of the several kinds of stones here mentioned one, or another, has to be used just because it is

not possible to get anything better locally and as the traffic on Indian roads is comparatively light, they wear tolerably well if the roads are properly looked after, but the hot dry climate of Upper India is against stone roads which "ravel," or loosen, on the surface, unless they can be watered regularly and this is practically impossible except on hill roads and in towns. The limestone road from Kathgodam to Naini Tal is watered daily in the dry weather and provides a surface that is satisfactory in every way for light traffic. Roads on the plains which cannot be watered daily break up very easily in the summer months, unless damp clay from the side ditches is spread lightly over them. Those in towns are often over-watered.

216. For use as "binding" disintegrated rock or "*bajri*" is generally used. Limestone bajri makes good binding material. Sandstone bajri does not, nor does sand. Occasionally a top dressing of kankar is used as binding and in parts of India "moorum" is spread on the rolled road. This is integrated trap and is sometimes used for making a road as stone or kankar is used.

217. The chief matter to attend to after once the quarry has been chosen, and the kind of stone that is to be used has been decided on is the size of the stone metal that the contractor should supply. Consideration of the matter will show that tough hard stone must be broken smaller than softer stone, if the same roller is to be used for both, and that for a given kind of stone, small stone will give a smoother road, but not necessarily a stronger one than large stone. The specifications of the United Provinces require that the stone metal should be one and-a-half inches in size and the stone should be uniform in size and quality.

218. The Road Board (of England) specification says:—"The roadstone is to be clean and free from all extraneous matter, of approved quality broken as cubically as possible and for normal traffic should comply with the British Engineering Standard Committee's standard for 2-inch stone. Where the road has to carry heavy axle loads, it is desirable that the size of soft stones, such as limestone, should be slightly increased. Broken stone specified as 2-inch gauge shall all pass through a 2-inch ring and shall consist of the following percentages by weight:—Not more than 15 per cent. passing through a $1\frac{1}{2}$-inch ring in every direction, not less than 65 per cent. over $1\frac{1}{2}$ inches and not exceeding two and-a-half inches in greatest length by measurement, not more than 20 per cent. over two and-a-half inches in greatest length. The screenings obtained by the use of a $\frac{3}{4}$-inch rod screen during the process of breaking should be kept separate and used as a top dressing during rolling operations."

219. The cost of working quarries and the operation of quarrying are matters that are beyond the scope of this Manual. Interesting particulars of the work as done in England will be found in "Road-making and Maintenance" by Thomas Aitken. Where stone is collected by hand in India and coolies are paid a daily wage of two annas for collecting and four annas for breaking, the rates will depend on the lead and on the daily task. Three specimen rate lists based on the Military Works Handbook are given below which do not include carriage by road and stacking at roadside :—

		Rs.	a.	p.
(*a*)	8 coolies collecting 100 c. f. at 2 annas.	1	0	0
	14 coolies breaking 100 c. f. at 4 annas, ...	3	8	0
	Mate and munshi, ...	0	8	0
	Baskets and rope, ...	0	4	0
	Cost of 100 cubic feet, ...	5	4	0
(*b*)	4 coolies collecting 100 c. f. at 2 annas, ...	0	8	0
	12 coolies breaking 100 c. f. at 4 annas, ...	3	0	0
	Mate and munshi, ...	0	8	0
	Baskets and rope, ...	0	4	0
	Cost of 100 cubic feet, ...	4	4	0
(*c*)	5 coolies collecting 100 c. f. at 2 annas, ...	0	10	0
	11 coolies breaking 100 c. f. at 4 annas, ...	2	12	0
	Mate and Munshi, ...	0	8	0
	Baskets and rope, ...	0	4	0
	Cost of 100 cubic feet, ...	4	2	0

For carriage, stacking, etc., the paragraphs on kankar collection should be referred to.

220. The cost of consolidation of stone varies with the locality, the quality of the stone, the water-supply, the means employed for consolidation. It is about double the rate for kankar consolidation.

221. There are two types of stone-crushers now in common use of which the older form, known as Blake's after the original inventor, was essentially an oscillatory crusher, no attempt being made to cube the material. Various improvements were made from time to time, and the machine which is now extensively used, and which has proved satisfactory in regard to breaking capacity, quality of material produced, and economical working, is that made by Mr. W. H. Baxter of Leeds. Various sizes are made. One most often used is a 16-inch by 9 inch machine breaking 60 to 80 tons per day. The stone is fed in at the top and broken between two reciprocating jaws actuated by very strong

machinery driven by an engine of about eight nominal horse power. The roller can be supplied on a movable frame on wheels, with an elevator, cylindrical screens for separating the broken stones into various sizes, and a delivery shoot.

222. Another form of stone-crusher is known as "Gates' Gyratory Rock and Ore crusher." Its mechanism is such that a crushing cone fitted on to a vertical main shaft with a certain amount of eccentricity impinges during its gyrations against the material to be broken and also approaches and recedes from, the sides of a strong casting in the shape of an inverted bell into which the material is fed, and between which and the cone it is crushed.

223. Codrington in "The Maintenance of Macadamized Roads" says that a good stone-breaker will break from quarried stone two cubic yards of hard limestone of the ordinary gauge in one day and some men will break more. Hard siliceous stones and igneous rocks can only be broken at the rate of one to one and-a-half cubic yard in a day. Of some of the toughest, such as Guernsey granite, a man can break on an average only half a cubic yard a day. River gravel, field-stone, or flints, which are already of a small size, can be broken at the rate of three or four cubic yards a day.

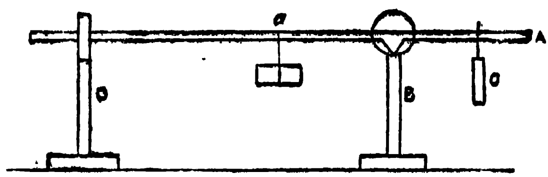
224. Such a large quantity cannot be taken as the daily task of an Indian stone-breaker, who may perhaps break 7 to 10 cubic feet in a day from stones or boulders that can be handled.

225. Road stones are tested in several ways and though the real test is the way in which the stone wears when used in a road, laboratory tests help to distinguish between those stones that may prove useful and those that will not.

226. One test is for abrasion. The best machine for this is one designed by Mr. de Courcy Meade and used by Mr. Lovegrove, Engineer to the Hornsey District Council, in an exhaustive series of tests on road stones. This is a rotary machine of three cylinders, each about one foot in diameter, with three one-inch angle-iron ribs arranged lengthwise in each cylinder. The stones are weighed dry, the same weight of each being put into the cylinders, and subjected to 8,000 revolutions at a speed of 20 revolutions per minute, after which they are again weighed, as well as the chips and dust produced by their abrasion. The same test is made with wet stones, half a gallon of water being put into each cylinder with the stones which are again weighed, when dry, after the test. A somewhat similar machine known as the Deval machine is used in France.

227. Specific gravity can be determined in a simple manner by means of Walker's balance. In the sketch—

Fig 44.



A is a steel bar, B is a rest in which A is supported on a knife-edge, about three inches from one end, and from this knife-edge to the other end, A is graduated into tenths of an inch. On the shorter arm is a movable weight C which can be placed at any suitable distance from the knife-edge. A loop in D checks undue swinging and a mark on D indicates the correct horizontal position. The sample to be tested is moved along the longer arm and, when it exactly counterbalances, the weight C, its distance from the knife-edge is noted. Leaving the weight C in its original position, the sample is completely immersed in a glass of water, no air bubbles being allowed to remain on it, and the distance b at which it now balances C is noted. As the specific gravity G is the weight of the sample in air divided by the difference of the weights in air and water, it follows that—

$$G = \frac{b}{b - a}$$

228. The absorptive properties of a stone can be measured by the same balance. The sample is first balanced by the counterpoise in any convenient position, the distance a being read off. It is then soaked in water for 24 hours and wiped clear of all superfluous moisture. Being heavier than before, it balances nearer the fulcrum, say, at a distance b. If x is the unknown weight of the sample, y the weight of absorbed water $\frac{x}{x+y} = \frac{b}{a}$ whence $\frac{y}{x} = \frac{a-b}{b}$ that is, the ratio of the weight of absorbed water to the weight of the substance. The percentage of absorption is represented by $100\frac{(a-b)}{b}$, so if $\frac{a-b}{b}$ equals, say, $\frac{1}{20}$, the absorption is 5 per cent., and so on.

229. Some engineers lay great stress on the cementing powers of a stone, which they test by wetting stone dust with water and moulding it into a short cylinder which after being dried is subjected to the blows of a dropping weight. Experiments show that quartzites, granite, gneiss, and marble possess very little cementing power, taking only two or three blows to break the briquette, limestones and some trap rocks give a briquette which will stand 30 or 40 blows, while other trap rocks give very variable results.

230. It is necessary to bear in mind the particular use to which a stone is to be put before its properties are approved, or condemned, for a stone which might not do for use as paving setts might still be of great service when broken up as macadam, or when used in a foundation course, as in Telford's system. Other stones which lack binding properties may be used on occasion, with advantage, in conjunction with some other material, such as loam or chalk. Durability depends partly on resistance to chemical decomposition, and partly on resistance to mechanical abrasion, and microscopical methods of examination are now much used to ascertain the composition of roadstones, but mineralogical composition alone will not determine the suitability of a stone, for it will sometimes happen that a very hard and durable stone cannot be used for paving purposes, because it wears smooth and slippery. Durability again does not always depend on chemical composition. Flint, for example, is chemically very stable, but it is also very brittle.

231. In the days of Telford and Macadam steam-rollers were unknown and the consolidation of stone was done by the carts, carriages, and horses that passed over it. Macadam held that under the influence of the traffic stones would unite by their own angles without the addition of any binding material, the ruts being raked in as the process of consolidation by traffic proceeded, but, though no binding was used, it was found that roads made in this way contained 20 per cent. to 25 per cent. of the whole coat in the form of muddy cementing matter, which must have been due to the wear of the stones during the process of consolidation, and the road-washings and scrapings which had worked into the voids of the coat of metal.

232. This being so it may be argued that it would be advisable to add some binding material to start with instead of letting it be formed by the gradual wear of the stones and this is done by some engineers, but, as a matter of fact, a perfectly consolidated road can be made with very little detritus in it, a road, too, that lasts better than one that contains a large quantity of so-called binding material. The solidity of a road depends chiefly on the quantity of stone it contains and the closeness with which it is packed and this solidity is diminished rather than increased by the presence of much small material.

233. The proper way to consolidate stone is to pack it well, to wet it thoroughly, and roll it thoroughly with a roller of the proper weight, and then to add a binding coat, say, one-third of an inch in thickness, just to fill up the surface interstices. There should be no binding material (paragraph 216) put in the body of the road. In the United Provinces the term "blinding" is used in referring to what is usually

called "binding." Both words are misleading, for "blinding" might imply the hiding away of inferior work under a thick coat of small stuff, while "binding" may lead to the idea that the individual stones in a road are to be imbedded in a matrix of small material, whereas they should be compressed into as solid a mass as possible, each stone interlocking into others by its angles, before ever the binding is put on to the surface of the road. By adding the binding to the surface only, a nearly impermeable crust is produced, and, with a proper cross-section, it should let very little water through to the sub-soil.

234. These remarks refer to roads made of clean, hard, angular stone broken as cubically as possible from large stone, but if gravel and shingle are used in road work, no amount of rolling will bind them and some loamy material must be added before consolidation.

235. Sometimes stone roads are consolidated in India in dry weather, but this is a mistake. Plenty of water helps the angular stones to interlock, without that wear on the corners that dry rolling produces and, from what has been said above, it follows that a road rolled when thoroughly wet is a far better road than one that is rolled dry, for the latter will contain the detritus that should be avoided. If plenty of water is availabe, and is used, the objection to rolling a road in dry weather is reduced, but not entirely removed, for water evaporates very quickly in dry weather in India, whereas during the monsoon the air is of full moisture. There will be some detritus even in a road that is rolled wet, especially if the road metal is soft and the roller is heavy, but there should not be much if the stone is hard and properly broken. Sometimes watering can be overdone as in the case of a new road which is not on a very firm bank and in such cases dry rolling, with a light roller, is advisable to begin with, or the stone will sink into the bank, as the water softens it.

236. The specifications of the United Provinces require that the old surface of a stone road should be scarified, to a depth of one inch to one and-a-half inches, before the stone of the new coat is spread, and also that no water is to be used when the new metal is being rolled until the pieces of metal have become sufficiently crowded together as not to be displaced by the roller. The need for digging up the old road is not apparent. In the case of kankar roads it was remarked that if the old surface is nicked with diagonal lines, the new coat wears into low ridges, with portions of the old surface exposed in the spaces between the diagonal lines; but this does not happen in the case of a stone road, in re-coating which it is sufficient to mend the old surface, if this is not beyond repairs, and to cross-nick it. Sometimes in India it is found

that the old surface is beyond repairs, and in such cases the old stuff must be removed to a depth of 1½ inches, or more, but, more often than not, repairing, cleaning, nicking and wetting the old surface will be enough. When, however, a specification says that the old surface is to be dug up the specification should be followed. That deep scarifying is often used is clear from the fact that mechanical scarifiers are provided with steam rollers, but the writer considers that their use should be limited to roads which are to be re-surfaced.

237. Then, as to watering, it follows that if the argument set out above is true, *viz.*, that there should be as little small stuff in the body of the road as possible, harm is done by heavily rolling the metal when it is dry. Notice how a stack of dry stone wears when compressed by anything heavy passing over it. The corners of the individual stones in the stack break off and are ground into small stuff. This does not happen to the same extent when the metal is being rolled wet, and though, as remarked above, there will always be some small stuff in a stone road when it is rolled wet there will be more if it is rolled dry, it is desirable to have as little as possible. Therefore, the road should not be rolled dry with a heavy roller.

238. It should, however, be stated that there are engineers who specify dry rolling. For instance, the English Road Board specification requires that "no water or binding should be applied until dry rolling has been carried out to a sufficient extent to form a smooth hard surface with the correct cross-fall with the stones well knit together and presenting a mosaic surface." And this system is followed in the United Provinces.

239. As regards the general arrangements to be made for road consolidation, for execution of the earthwork and for lights and danger warnings, the article on kankar consolidation should be referred to. A steam roller and arrangements for working it are advised for a stone road, but often the consolidation may have to be done by means of rollers, iron or stone, drawn by cattle or by men.

240. Steam rollers are of various weights and sizes. A 15-ton roller with 18-inch driving wheels and weighing 16¼ tons, when in working order with scarifier attached, will give an inch width pressure of nearly 5½ cwts., a 12-ton roller weighing 13 tons when in working order, and having driving wheels 17 inches wide, will give an inch width pressure of 4½ cwts., and a 10-ton roller with 16-inch driving wheels, and weighing 10¾ tons in working order, will give an inch width pressure of nearly 4 cwts. Carts, motor lorries and traction engines will bring a greater pressure on to a road; nevertheless experience shows that good work is

done, in the case of soft material such as limestone, by a light roller of 7 to 10 tons, while hard and tough igneous rocks give the best results with a heavy roller of 15 tons, which should not, however, be used on soft and yielding road beds. Some counties in England, which can afford it, have a series of rollers of different weights as a 15-ton roller for roads in county districts where there are no underground pipes to damage, one of 10 tons for city use to avoid damage to pipes and for repairing patches, and a light roller of 6 tons for steep gradients and light work generally, and Mr. Pickering the Borough Engineer of Cheltenham, has designed, for patching purposes, a steam roller and water tank combined which is referred to in the chapter on maintenance. Compound rollers cost more than single cylinder rollers, but are more economical in fuel and water consumption, are less noisy and easier to handle, and last longer.

241. When the road surface has been prepared, the stone metal should be spread on it and closely packed by hand. If the road is a new one, with a foundation course, this course will be laid first on the new road bed which has been properly shaped and rolled or rammed. It may not be possible to roll it with the heavy roller, as the soil may be compressible, but light rollers of stone or iron may be available, failing which the road bed, or sub-grade, can be well rammed. The foundation, consisting of large stones hand-packed as in a Telford road, or of stones of 3-inch or 4-inch cubes or brickbats, would then be laid, the depth depending on the class of road and the amount of traffic likely to be carried. Bricks laid flat move easily and do not make a sound road bed for heavy traffic. This foundation course, or soiling, or bottoming should be rolled dry or rammed, if the soil will not stand rolling, and its surface should be brought to a regular and uniform contour.

242. Some engineers lay on this foundation course a layer of sharp clean sand or fine gravel, 1½ inches to 2 inches thick, to receive the top metal, having previously treated the foundation course to a blinding of sand or gravel well brushed into the joints during the final stages of its consolidation. The object of this layer of sand or gravel is to prevent the metal coating especially if it is not very thick, from being crushed between the foundation course and the traffic. This is not recommeded. Modern practice accepts the system of a well compacted foundation, supporting the upper coat without movement, a method which cannot be assured if a cushion of sand is introduced above the foundation. This is, however, used in brick and wood pavements.

243. The layer of stone 4½ inches thick should be packed over the foundation, wetted and rolled and finished with binding. The second coat of 4½ inches should be laid over the first and wetted and rolled and

finished in the same way. In the case of an old road there would be one 4½-inch new coat only which would be laid on the old surface after this had been cleaned, patched, nicked and wetted; but if the idea was to re-surface with a 3-inch coat, it would be necessary to dig up the old surface to a depth of 1½ inches (or more, if this was indicated as advisable) to separate the excavated material into what was obviously useless (except, perhaps, after screening, for use as binding) and what could be usefully mixed with the metal collected for the re-surfacing, and then to spread the metal.

244. The construction of the side walls of clay, the spreading of the metal and its consolidation would proceed in sequence as indicated under kankar consolidation and should be so arranged as to avoid over-lapping or delay. The quantity of work to be done daily will depend on the work itself, that is, whether it is new work, or renewal, or re-surfacing, on the nature of the road metal, on the ease with which water can be procured, on the interruptions caused by passing traffic, on the roller used, and on the gradient. Messrs. Aveling and Porter estimate 1,000 to 2,000 square yards of an ordinary coat as likely to be rolled in one day and this should cover the majority of cases, and if the former figure is taken as the day's work, 750 feet of a 4½-inch coat on a 12-foot road can be rolled in one day. It would be easy, therefore, to do a furlong a day, but, to allow for accidental delays, 10 days might be taken for each mile. More than this can be done with proper arrangements and good supervision as, on the other hand, less can be accomplished and not done well.

245. If a 15-ton roller is used, the driving wheels of which are 4½ feet apart and 18 inches wide and the front wheel 4½ feet wide, the roller can do half the width of the 12-foot road in one trip, and if it travels 14 miles in a day of 7 hours at 2 miles an hour, it will roll a furlong 56 times. During this time the driving wheels will have gone over the whole surface about 24 times. Their pressure on the road is about 5 cwt. per inch width or about double that of the front rollers. The 4½-inch coat of metal will, if work proceeds at this rate, have to be spread at the rate of a furlong a day, and the road surface must be nicked at this rate, the building of the side walls of clay keeping pace with this work. Larger labour gangs are, therefore, wanted than are needed for kankar consolidation.

246. Consolidation is effected by watering the new coat of metal thoroughly and taking the roller over it as often as is necessary to compact the stone. In the case of a new road, water is used sparingly at first to prevent the softening of the sub-soil. Wherever this is possible, water should be applied through sprinklers from proper water carts. The rolling should begin at the edge of the road, the roller

moving up along this edge and returning on the other, and during each succeeding trip the edge of the strip previously covered by the driving wheels should be overlapped, while another strip nearer the middle of the road is covered. The rolling thus proceeds gradually from both sides towards the centre. It should be continued until the stone ceases to creep in front of the roller and is firm under foot as one walks over it, and smooth and looking like an encaustic pavement, and until the stones adjacent to where the foot presses as one walks do not move. The binding may then be spread over the surface in a layer about one-third of an inch thick, and well watered through a spray, and the rolling should be continued until the whole surface is thoroughly compact. Any surplus binding material not incorporated with the road must then be swept off.

247. It is not always possible to obtain a steam roller for the work of consolidation. A few years ago stone rollers were used which were, perhaps, 4 feet in diameter and 3 feet long, giving a pressure of 188 of lbs. per inch-width which could be raised to 210 lbs. when the frame was loaded, but their place has been taken by iron rollers of the above dimensions. These weigh 2 tons and give an inch-width pressure of 124 lbs. when unloaded, and of 228 lbs. when fitted with scrap increasing to 310 lbs. when the frame is loaded. Other patterns are also available. They can be drawn by cattle, or by men, and they are not nearly as efficient as steam rollers, taking much longer over the work and not doing it so well. Owing partly to the time taken in consolidating a road, with the consequent need for letting the traffic on to it before it is ready, the binding is put on too soon, the traffic disturbs the surface of the road, the roller goes over it again, there is more binding added from time to time, and in the end the road is not a thoroughly compacted mass of stone with a surface completed with binding material, but an accumulation of stone in a setting of binding and, therefore, not a good road.

248. In France iron rollers 6 feet in diameters and 5 feet long, weighing 3 tons when empty, 6 tons when full, and 9 tons when loaded, are sometimes used, and it is said that 8 to 10 rollings are sufficient with a 4½-inch coat, 2 or 3 rollings dry with the roller empty, 2 or 3 rollings with blindage and water and with an empty roller, 2 or 3 rollings with the full roller, and one or two about a week or 10 days after the road is opened to traffic. This light consolidation appears insufficient for good work. There is no doubt that a road can be made to look as if it were consolidated even when the work done is insufficient, and when steam rollers were first used in Central India, progress at the rate of a mile a day was not unknown, but good sound work cannot be expected, except when it is slowly and thoroughly done.

CHAPTER IX.

ROAD MAINTENANCE.

249. To maintain a road in good order it must not only be renewed, or-surfaced, or have the rust in its surface filled at varying intervals, but it must also be patched continuously. In the early days of modern road-making continuous patching was not done and roads, badly made and indifferently repaired, were never satisfactorily maintained, and it was not till the end of the 18th century that a proper system of repairs was introduced.

250. The renewal or re-surfacing of the road surface has been considered in an earlier chapter. Patchwork is now dealt with. As the road surface deteriorates from month to month, under the wearing action of the traffic and the weather, it has to be patched to keep it from going to pieces altogether, and the sooner holes are mended the better it is for the road. Prevention of damage is the secret of success. It is bad economy to let the surface of the road remain neglected, for holes not only collect water which causes extra wear in them, in addition to damage to the undercoat, but they are the cause of increased concussions which inconvenience the travelling public and damage the road.

251. The road engineer in India cannot prevent all kinds of vehicles with all kinds of tyres coming on to roads, except in the case of heavy motor traffic which is regulated by law, and he will find damage done by narrow tyres fitted on small wheels of heavily loaded carts, or by wheels that wobble as they roll. He will not, however, find his road called upon, at present, except, perhaps, in Presidency towns, to carry anything like the traffic that is carried by many roads in England, and what he needs, in order to maintain the surface in good order under present conditions, is good consolidation of good materials followed by continuous effective patching as soon as this becomes necessary.

252. For the work of patching a sufficient supply of kankar, or stone, is required, and gangs of beldars known as "naukar coolies" or "*bàramasis*," under a head coolie, or a mate, with digging tools, rammers, water carts, etc. The supply of road metal for each mile of road will depend on its condition and should be carefully considered before the metal is collected, for otherwise it will happen that there will be more metal in some places than is needed, and less in others, and the road gang will waste time in carting materials from one place to another The road metal must be clean and hard and broken to a size of 1½ to 2 inches as specified under collection, and it should be stacked on earthen

platforms built off the travelling surface of the road, in stacks which may measure 5 feet average width by 13 inches in height. These stacks may be marked, at 5-foot intervals along their length, with 3-inch bands of white wash, after they have been paid for. These bands enable an inspecting officer to see how much material remains on the road and at the same time to differentiate between material that has been, and that remains to be, paid for. Stacks of metal that have not been paid for should not be drawn upon for use as repair metal.

253. The road gangs should consist of a mate, or a head coolie, and 8 or 10 coolies, and their work should extend over 8 or 10 miles. Smaller gangs should not, as a rule, be kept on the road. Each gang should have a light hand-cart for metal, a small hand-cart for water, picks, rammers, "*phaurahs*," templates, flags, hammers, baskets, twine and iron pegs, and anything else that the particular work in hand may need. Sometimes two water carts are required, if the water-supply is at any distance, of which one may be a barrel on wheels, or a galvanized tank on wheels. This would have straight shafts and a tap. The smaller water cart might be an empty oil drum or paint drum, swivelled on to, and removable from, a wheeled iron frame with two legs and with handles like those of a perambulator. This hand water-cart can be moved about by one man, the barrel can be rested on the ground and the framework removed, but it is not essential to the work for any light water cart will do. The templates are required for checking the cross-slope of the road, especially when the "*patris*" are under repair when the twine and pegs are also required in order to secure an even edging to the new earthwork.

254. The duties of the mate and coolies are to do all necessary repairs, to see that drainage is not obstructed, that the road is kept free for traffic, including the lopping of overhanging branches of trees, that weeds and plants do not grow in the joints of masonry culverts, etc., and to follow any special directions given in the mate's order book. *See* also paragraphs 260 to 263. The mate should report all damage that cannot be put right by the gang and all accidents that affect the road. He should keep, in a tin case, a muster roll in the form prescribed for use on roads, and should post it up daily in ink, and he should always have this with him, as well as a mate's order book. This is a strongly bound blank book in which the sub-divisional officer records in half-margin such directions as "Repair the road surface in miles 2, 3, 4." "Cut down *patris* in mile 4 to the proper slope of one inch in three feet." "T[illegible] overhanging branches to a height of 10 feet in mile 3."

255. The sub-overseer should see that these orders are carried out and should enter a remark in the order book recording their completion. Ordinarily he gives no orders, for the sub-divisional officer should enter enough for the gang to work at till his next visit, but occasion may arise which requires him to take action when he should record his directions, and the fact of their having been carried out, in the mate's order book. This system is not always followed. Some officers say that the sub-overseer should never give any orders, others require him to give all orders, and do not supply the order book to mates, but require the sub-overseer to keep two note-books, one of which is sent weekly to the sub-divisional officer to enable him to see what is being done. Experience shows that the mate's order book system works well in practice, if the sub-divisional officer gives sufficient and clear instructions.

256. As soon as a hollow is noticed in the road surface, it should be filled up. Hollows are usually oval in plan. Patches are generally rectangular. This means that they are either too large or too small. There is really no reason why they should not be of the same shape as the worn portion. This is recommended by Codrington in "Road Maintenance."

257. They are generally made three inches deep. There is no reason why they should not be two inches deep, or less, if the traffic is light and the hollow is not deep. When the excavation for the patch is ready, it should be filled with clean metal, any serviceable material that comes from the patch being added, but not stuff of which the corners have become rounded. The surface of the filling should be higher than the road surface. The filling should be rammed with a sufficiency of water and in the case of kankar no binding of any kind should be added, but with stone metal screenings of the stone should be added before the remming is finished. The patch should be kept wet for a day and may be covered with damp leaves to secure this when the weather is very dry. When the consolidation is finished, the surface of the filling should be level with the surface of the road.

258. The ordinary road-roller is not suitable for patchwork, but Mr. J. S. Pickering, M.I.C.E., Borough Engineer of Cheltenham, has designed a steam roller and water tank combined which has proved to be a success in the systematic patching of macadamized roads. It carries a water tank of 200 gallons capacity the top of which is formed into an iron box in which cast-iron blocks are placed to enable the weight on the rolling wheel to be adjusted to the work it is required to do. This rolling wheel on which the bulk of the load is concentrated is made to bear, by adjustment of the loads, a load varying from 4 tons 7 cwts, to 9 tons 10

cwts. The metal used for patching is drawn by the roller in a cart which carries about two tons. When not required for road repairs the engine may be used as a tractor, or for street watering, a tipping body to carry four tons, and a water tank to hold 1,000 gallons being made interchangeable. This roller can travel at the rate of six miles an hour, but during rolling the speed is reduced to two miles an hour. The reversing action of the engine is so sensitive and easy that the roller can be made to pass over a patch 18 inches long no less than 30 times in a minute. Where there are many stone roads, a roller of this kind might be very useful, but, at present in India, patching on stone roads is done with rammers such as are used on kankar roads.

259. Sometimes ruts form in a road. For patching in these a roller would not be of use. Ruts are not found so frequently on a stone road as on a kankar road. They should be kept under as far as possible by rut-filling or, if this cannot be done owing to want of funds, by what is known as "*lik katai*" or the spreading of screenings in the ruts. This is a barbarous practice at best, and if it can be avoided so much the better. When it has to be used, it should be so done that it will not be a source of danger to traffic. When a road has been well consolidated after careful hand packing, it ought not to run to ruts if the surface is swept every day and traffic marks are obliterated till all danger of ruts forming has passed, as it will pass in the case of most roads that carry mixed traffic. Roads that do not carry mixed traffic are always liable to "track," and in America attempts are made to prevent the formation of ruts due to the passage of heavy slow-moving teams by putting up direction boards, by placing on the road piles of stone or barricades to direct the traffic temporarily, forcing the traffic to move sometimes in gentle serpentine curves, and sometimes in lines parallel to the ruts, the barriers being changed from time to time so as to force the traffic over every part of the road; but this method of limiting the travel is used only on comparatively wide roads and is, even then, held to be indefensible owing to the obstruction of traffic. In India the roads that "track" are not the wide ones, but those that are made narrow, because there is not much traffic on them. On such roads "*lik katai*" is not as dangerous to traffic as on roads carrying much mixed traffic, but warning boards for chance motorists should be put up where it is resorted to. "*Lik katai*" should be done when ruts begin to form by spreading small kankar "*bajri*" along the ruts or sweeping the surface "*bajri*" into them and strewing earth lightly over the whole surface and sweeping it every day for a few days. On no account should

large lumps of kankar be used. It is very necessary to put a man in charge of the work who knows what to do. He should move the "*bajri*" and divert the traffic every second or third day, or the road will soon have not two, but half a dozen ruts. Branches of trees and pieces of wood put over the places where ruts are forming do no good, for they merely narrow the road and aggravate the evil. If by neglect the ruts become an accomplished fact, they should be mended by cutting out trenches 18 inches wide and 3 or more inches deep, and filling these up with metal and consolidating it. This is called rut-filling.

260. Holes for earth for repairs to the road should not be dug by the coolies from all over the road land. There ought to be along the road boundary borrow pits about 50 feet long, with cross-bars of earth between two pits, and it is from these pits that earth should ordinarily be taken, neatly and methodically, but the formation of borrow pits should be avoided altogether in the neighbourhood of inhabited areas, where no excavations should be made that cannot be drained. No earth should be dug within five feet of a tree, milestone, furlong post, or boundary pillar, or any masonry work.

261. The road gangs are usually employed all the year round, whence the term "*baramasis*" by which they are known, but some officers prefer to vary the number in each gang according to the season, doing all the road repairs in the rainy season and winter, and practically no work in the dry season, for patch work done in the dry season does not last as well as that done when there is moisture in the air, and earthwork done in the dry season soon turns to dust and is blown away by the high winds that precede the arrival of the monsoon. There are varying climates even in one province and no precise methods of work can be prescribed that apply to all, nor should an officer, who is moved from one part of a province to another, introduce his particular methods without giving the local methods a fair trial, unless they are obviously wrong. As a rule, they contain something for him to study and adopt.

262. Road gangs prove of use when flood damages occur to the embankments of bridges and culverts, but their work in the further prevention of damage and its repair has to be supplemented by that of special labour gangs, or petty contractors. The damage done by sudden heavy floods is usually the cutting back of embankments behind bridge abutments either by eddies below a bridge, or by the flood water overtopping the bank, the creation or scour holes under a bridge of which the waterway is insufficient, the breaching of a road where there is no bridge, and the roughening of the metalled surface of the road where

TABLE OF REDUCED BED LEVELS

RECORDED IN APPROXIMATE REDUCED LEVELS OBTAINED BY SOUNDINGS BASED ON BENCH MARK GIRDER BED LEVEL 100.

Stations.		Bed levels reduced from soundings taken.				Remarks.
Group.	No.					
A Up Stream	1					
	2					
	3					
	4					
	5					
	6					
	7					
B Up Stream	1					
	2					
	3					
	4					
	5					
	6					
	7					
C Centre	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
D Down Stream	1					
	2					
	3					
	4					
	5					
	6					
	7					
E Down Stream	1					
	2					
	3					
	4					
	5					
	6					
	7					
F Down Stream	1					
	2					
	3					
	4					
	5					
	6					
	7					

To go with para 265.

No. 639-18-1500

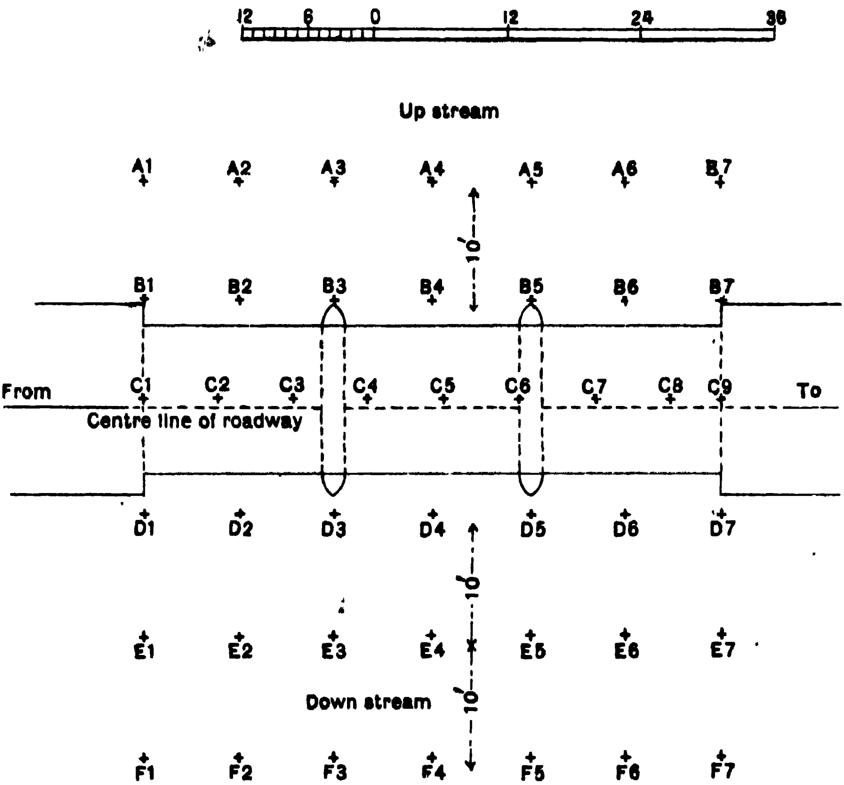
ANNUAL INSPECTION CHART OF BRIDGES 20 FEET SPAN AND OVER

GIRDER BRIDGE OF 3 SPAN OF 16 FEET EACH SITUATED IN THE 8TH FURLONG OF MILE 16 OF THE ROAD IN THE

DISTRICT OF DIVISION

SITE PLAN

Scale of Feet.



REFERENCES.

Karwan Nadi Bridge

12 feet Roadway Brick-on-edge

Concrete Floor

Foundations

Abutment ordinary concrete 4' thick

Soil Stiff Clay

REDUCED LEVELS.

1 Bench mark
Girder bed plate .... 100·00

2 Roadway .... 101·50

3 High flood .... 101·00

4 Floor .... 93·00

5 Under Surface
Foundation Concrete .... 90·40

To go with para 265.

No. 639—16x1300

flood water flows over it. Sometimes guide bunds, or Bell bunds, above or below a bridge are breached. In all these cases the gang should take such action as is obvious, and also report the fact that damage is being done by the flood. To prevent the cutting away of a road bank, they should check the force of the water by branches of trees, etc.; to prevent the overtopping of a bank they should raise a small bank along the edge of the road, for once the water is over it, and cutting back begins, they will not be able to do much to stop a breach in the road. They can also do something to fill up scour under culverts by means of pitching, if it is available, or to check it by throwing in leafy branches of trees.

263. The road gangs should, in fact, attend to everything connected with the upkeep of the road that can be done by them, keeping it open for traffic and removing all long grass and jungle from the "*patris*" as well as from the compounds of inspection bungalows. Sometimes naukar cooly huts are provided for them to live in, at other times, some of them sleep in the out-houses of inspection bungalows and some in their own homes in villages near by. As a rule, they are given a day off on Sunday to enable them to visit a market to buy food.

264. The re-painting of milestones, furlong posts, boundary pillars, motor sign-posts put up in accordance with the Act should be done annually by contract, or daily labour, immediately after the rainy season. Broken milestones, furlong posts, etc., should be renewed as soon as possible. It is usual to paint on the face of milestones the date of last renewal, and for this purpose it is sufficient to use two figures only to represent the year, or four in all, two on the right, *e.g.*, 08, representing that the mile on the right was dealt with in 1908, andl two on the left, *e.g.*, 12, indicating that the mile on the left was done in 1912. Particulars as to what was done, *i.e.*, renewal, or re-surfacing, or rut-filling, can be obtained from the register. To attempt more than is here indicating merely crowds the face of the milestone with figures from which the essential figures cannot be picked out easily as one drives by. The figures should be in red, as the mileage will be marked in black. Furlong stones are usually painted white with figures picked out in black.

265. All bridges should be inspected before and after the rains and levels above, under, and below bridges of 20 feet span and over should systematically be recorded in such a form as that shown opposite, the use of which may be extended to bridges under 20 feet span which may show signs of scour. These levels show whether scour is taking place. Scour directly under a bridge generally needs attention, but is not dangerous, if the bridge has deep foundations and the scour is

not deep. It shows that the waterway is restricted. If more waterway cannot be provided by adding spans, the approaches may be lowered and the bed of the stream pitched with block kankar or stone. Scour above, or below, a bridge and at some distance from it is not immediately dangerous, but if it continues to extend towards the bridge, it needs attention. Straight guide bunds, or Bell bunds, below a bridge will serve to move the point of action of an eddy from the bridge face to the end of the bund. A part of the bund may disappear. This is better than losing the bridge or culvert. Similar bunds above the bridge or culvert will preserve the road bank. If a stream, as it winds from side to side, threatens one approach or the other, the bund forces it to curve around its nose, which is strongly protected, the velocity along the face of the embankment is checked, and silt is deposited, protecting the road. For details of Bell bunds, and of bridges, the student is referred to the Manual on Bridges and Sir F. Spring's book on river protection in the Techincal Series. In the present Manual it is sufficient to draw attention to the few points given above which relate to the protection of the road.

266. When a road has been cut through by floods at a point where it is impracticable to build a bridge on account of the expense of construction and upkeep, it may be advisable to put in an Irish bridge, or dip, consisting of strong side walls 12 feet or 16 feet apart, well pitched, upstream and down-stream, and with a reinforced concrete foundation six inches deep to the metalled roadway. If the reinforced concrete is omitted, and the side walls are of any height above country level, the action of the water will scour out the metalling and the earth filling between the walls. As a rule, Irish bridges are not made where the bank is high, and the top of the side walls usually coincides with the level of the country, and there is no great action tending to scour out the earth between the walls. It is only in the case of deep scour and a high bank that special precautions are necessary.

267. It is important that the road engineer should know when each mile was last consolidated, and a register containing this information should be kept up. The information is contained in the Road Chart which is a graphic record of collection and consolidation on each mile and furlong of a road and which serves well for office use. Something simpler is needed for an officer whose work takes him on the road, and it is suggested that the record should be in a pocket book and in this form :—

Mile.	Date of consolidation.			O Rut-filling □ Re-surfacing.
Mile 2, ..	03	08	14	
„ 3, ..	05	09	14	
„ 4, ..	02	07	12	
„ 5, ..	01/2	07	12	

and in this :—

Year.	Work done.	Average expenditure per mile.
1901	$\frac{5}{2}$	
1902	4	
1903	2	
1904		
1905		
1906	3	
1907		
1908	4 5	
1909	2	
1910	$\boxed{3}$	
1911		
1912		
1913	4 5	
1914		
	2 3	

with a column in the last case showing the average expenditure for the year per mile on collection, consolidation, and maintenance, omitting the cost of repairs to bungalows and bridges and money expended on arboriculture. A square round a figure would indicate re-surfacing and a circle rut-filling. Half a mile or a quarter or an eighth could be indicated by the figure 2 or 4 or 8 as a denominator. Any other convenient record could be used instead.

268. Every year, after the monsoon, the depths of metal on the road should be taken in each mile. Sometimes this is done in miles only that are to appear in next annual estimate for collection, but this is not enough, for it is very important that there should be a record of what thickness of metal remains in each mile. The measurements are generally made in 9 holes, about 6 inches in diameter, or less, dug in each mile, of which 3 are nearly opposite a milestone, 3 at the 4th furlong and 3 nearly opposite the next milestone, one in each case being at the middle of the road and one near each edge. The average of three is taken and then the average of the three averages. This is recorded as the mean depth. The system is not reliable in cases in which one section of a mile is thicker than the rest, and measurements which give abnormal results should be disregarded, or the thickness of the sections should be shown separately. When the holes are dug, they should be filled with loose pieces of kankar, or stone, and as soon as they have been inspected, the kankar, or stone should be consolidated into them, for if the holes are left open they may be the cause of accidents.

269. Given the statement of the depth of metal and the registers of consolidation shown above, an officer in charge of a district soon sees that

some miles need early renewal, that some last longer than others, that new consolidation has not added as much to the thickness of the road as it should have done, and his inspection will show him whether the reason for the former is heavy traffic, or poor metal, or bad repairs, and he can ascertain why the consolidated coat is thin. In the same way, an officer inspecting a road ought to know when the young avenues were planted. This information he can get from the arboricultural programme.

270. The preparation by a senior officer of complicated detailed statements, mile by mile, representing, by letters used as a kind of shorthand, the state of the road surface, the condition of the earthen sides and of the avenues under operation, the work that is being done on collection, consolidation and the collection of petty repair metal is not advocated by the writer. Junior officers should occasionally make full records of their inspections, and senior officers should refer to these when they inspect the roads, confining their remarks to matters that need to be attended to.

271. The quantity of road metal that will be used in maintaining a road will depend on the traffic, on the quality of the metal, the age of a mile, and the way it has worn and on the effectiveness of the patchwork. In some places a mile will not have a three-year life, in others miles last for ten or more years, though they are repaired less than in the former case. In framing estimates for maintenance it is necessary, therefore, to discriminate between various miles. Sometimes not more than 200 cubic feet of metal will be needed for the year's work, at other times 1,000 cubic feet may be usefully employed, and in very special cases it may be necessary to use much more than this. For ordinary traffic the yearly expenditure of metal may be 200 cubic feet per mile per year of the age of the mile, and petty repair metal may be collected on this scale to begin with. At the same time there should be a reserve of about 500 cubic feet in each mile which should not be used without the District Engineer's permission, and more than the quantity indicated above should be collected if any mile suddenly shows signs of breaking up more than was anticipated.

272. If traffic returns can be obtained, they may prove useful in indicating what wear of a road is to be expected in normal circumstances, but so much depends on the quality of the metal, and the way the consolidation is done, and on the weights carts are allowed to carry, and the kind of tyres they are allowed to adopt, that too much faith must not be put in traffic returns unless they are carefully compiled on a standard system. In Liverpool Mr. Brodie, M.I.C.E., the City Engineer, records the tonnage life of roads by taking occasional records of the numbers and classes of vehicles passing along the principal streets, and assigning

loads to each class, reducing the results to a standard of tons of traffic per yard-width of carriageway per annum, thus eliminating the error that a record of numbers of vehicles, without their estimated weights and without mention of the width of a road, is likely to produce.

273. But more useful than the collection of statistics is attention to details of the work. With good metal, properly consolidated and effectively repaired, a road will last considerably longer than it will if inferior metal is badly put down and if repairs are indifferently done.

NOTE.—For brief remarks regarding the maintenance of hill roads and earth roads paragraphs 168, 295, 310 should be referred to

CHAPTER X.

ARBORICULTURE.

274. If he notices the difference between a road without trees and one that has good avenues every road engineer will take an interest in arboricultural operations, and will endeavour to improve his roads for the sake of the public by planting out trees which, if judiciously chosen, will give shade to travellers and prove a source of revenue as well.

275. Before effective arboricultural operations can be undertaken, a scheme of planting should be drawn up, and the example given below will help to show how this can be done. This method was adopted by Mr. Verrières, C.I.E., Executive Engineer, Agra Provincial division, and leads up to the form prescribed for use in the preparation of arboricultural programmes in the United Provinces :—

Example of notes for arboricultural operations.

1. In a mile of double avenue trees planted at 30 feet intervals number 350 in round numbers.
2. Cost of planting a full mile of double avenue and maintaining it for one year :—

Digging pits 350 × 3 × 3 × 3 = 9,450 c.ft. at Rs. 2-8-0 per $^0/_{00}$ = Rs. 24, ...	Rs. 326
Collecting good soil 9,450 at 8 annas per cent. = Rs. 48	
Digging up seedlings from nurseries not more than 5 miles away and planting 350 at Rs. 5 = Rs. 18, ...	
350 earthen thonlas at 5 annas each = Rs. 110, ...	
350 earthen gharras at 350 pies each = Rs. 6, ...	
2 bhistis or malis for upkeep at Rs. 60 = Rs. 120, ...	

3. Cost of maintaining double avenue full mile for second year, 2 miles at Rs. 60 = Rs. 120.
4. Cost of maintaining a double avenue full mile for 3rd, 4th, 5th years, 1 mali at Rs. 60 = Rs. 60.
5. A mile of gap-filling will be reckoned as half a full mile.
6. Trees will be planted at intervals of 30 feet and 18 feet from the edges of the metalled portion of the road.
7. In gap-filling the trees planted will be in keeping with those of existing avenues.

8. In new miles neem trees and, where possible, shisham trees will be planted, as only these trees grow in the district.

References.

A indicates Established avenues.
B „ Avenues with gaps to be filled.
C „ Lengths under operation : whole avenues.
D „ „ „ „ : gap-filling.
E „ Trees irregularly planted, including babul and jungle trees.
F „ Avenues too far from the road to be of use.
G „ No trees of any kind.
H „ Bazars, river beds, etc.

Statement of Avenues on the Road.

Mile.	Furlong.								Planting required.	Year.
	1	2	3	4	5	6	7	8		
1	H	H	H	H	H	H	H	H		
2	H	H	F	F	F	F	F	F	New 6F Gap-filling 4 miles in 3, 4, 5, 6, 7/8 equals 2 miles.	1908-09
3	A	A	A	B	B	B	B	B		
4	B	B	B	B	B	B	B	B		
5	C	B	B	B	B	B	B	B		
6	B	B	B	B	B	B	B	B		
7	B	B	B	B	A	A	A	B	Gaps 2 M, 1F in 7/8, 8, 9 equals 1-0-330 new.	1909-10
8	B	B	B	B	B	B	B	B		
9	B	B	B	B	B	B	B	B		
10	G	G	G	G	E	E	E	E	New 2 M, 3 F in 10-11-12.	1910-11
11	E	E	E	G	G	G	G	G		
12	G	G	G	H	H	H	H	H		
13	G	G	E	E	G	G	G	G	New 2 M, 2 F in 13-14-15.	1911-12
14	G	G	G	G	G	H	H	G		
15	G	G	G	G	H	H	H	H		
16	G	G	G	G	G	G	G	G	New 1 M, 1 F in 16-17.	1912-13
17	G	Road ends								

ESTIMATE.

			Rs.	Rs.
1908-09	Plant 2M, 6F at Rs. 236,	...	896	903
	Maintain 3rd year 1F in mile 5 at Rs. 60,		7	
1909-10	Plant 1-0-330 at Rs. 326,	...	346	684
	Maintain 4th year 1F at Rs. 60,	...	8	
	„ 2nd year 2M, 6F at Rs. 120.	...	330	
1910-11	Plant 2M, 3F at Rs. 326,	...	774	1,074
	Maintain 5th year 1F at Rs. 60,	...	7	
	„ 3rd year 2M, 6F at Rs. 60,	...	165	
	„ 2nd year 1-0-330 at Rs. 120,	...	128	
1911-12	Plant 2M, 2F at Rs.32,6,	...	733	1,247
	Maintain 4th year 2M, 6F at Rs. 60,	...	165	
	„ 3rd year 1-0-330 at Rs. 60,	...	64	
	„ 2nd year 2M, 3F at Rs. 120,	...	285	
1912-13	Plant 1M, 1F at Rs. 326,	...	367	1,009
	Maintain 5th year 2M, 6F at Rs. 60,	...	165	
	„ 4th year 1-0-330 at Rs. 60,	...	64	
	„ 3rd year 2M, 3F at Rs. 60,	...	143	
	„ 2nd yarr aM, 2F at Rs. 60,	...	270	
1913-14	Maintain 5th year 1-0-330 at Rs. 60,	...	64	477
	„ 4th year 2M, 3F at Rs. 60,	...	143	
	„ 3rd year 2M, 2F at Rs. 60,	...	135	
	„ 2nd year 1M, 1F at Rs. 120,	...	135	
1914-15	Maintain 5th year 2M, 3F at Rs. 60,	...	142	345
	„ 4th year 2M, 2F at Rs. 60,	...	135	
	„ 3rd year 1M, 1F at Rs. 60,	...	68	
1915-16	Maintain 5th year 2M, 2F at Rs. 60,	...	135	202
	„ 4th year 1M, 1F at Rs. 60,	...	67	
1916-17	Maintain 5th year 1M, 1F at Rs. 60,	...	67	67
	Total,	...		6,008

276. To these figures should be added incidental charges for nurseries, sheltering trees from frost, etc. Nurseries can often be maintained for very little if they are planted in the compounds of inspection bungalows and are looked after by the "*chaukidar*." Occasionally trees have to be bought and their cost must then be added to the cost of planting when the estimate is being prepared. Funds will not always admit of

all the planting on a road being done in five years and the programme of operations must then be framed according to the money which will be available.

277. For details of work the local Manual of Arboriculture should be consulted, as conditions will vary in each province. The information given below is condensed from the Arboriculture Manual of the United Provinces.

278. Before tree planting is undertaken in any district, a review of the condition of each road as to existing avenues and to suitability of soil for planting new trees should be made. A programme of operations should then be drawn up in consultation with the Director of Agriculture. This should cover the work for five years and should provide for planting trees, like those which are growing near the road, in full miles where there are no avenues and in gaps where avenues exist.

279. Full miles are to be preferred to gaps, and trees of one kind should be kept together. Gap-filling is more expensive than the planting of full miles of young trees and less likely to be successful, for the young trees in gaps are often killed by the full grown trees near them.

280. Mango, jack, "*mahua*," "*jamun*" and tamarind are the best trees for shade and fruit in the United Provinces, but naturally they will not do well everywhere. Even in the United Provinces the mango tree does not flourish south of the river Jamna, while the "*mahua*," which does not thrive in cold districts, does well in Bundelkhand. The jack, again, does best in the damper eastern districts and the "*jamun*" is well suited for tracts which are too wet for the mango. The "*mahua*" and the tamarind need special protection from frost.

281. All these trees are raised from seeds in nurseries and can be planted out in the rains. They should be planted at distances apart of 40 feet, except the tamarind which needs intervals of 60 feet. Other trees suitable for planting are those of the fig order ("*bargad*," "*gular*," "*pakhar*" and "*pipal*") and the "*shisham*" (for its timber) and "*neem*." In the worst soils the "*babul*" can be grown. The "*semal*," "*siris*," "*tun*," "*neem-chameli*" "*kachnar*," and millingtonia should not be planted.

282. Nurseries should be established at suitable points, generally inspection bungalows, where shade and water are available and the soil is good, and twice as many trees as are likely to be required should be planted out under the care of the bungalow chaukidar, if he understands trees. They should be inspected frequently. The seeds should be sown in lines six inches apart, and the soil should be light and well

manured with leaf mould, but, at the same time, not too sandy, or it will be difficult to get balls of earth to adhere to the roots of the plants in transplanting. From four to eight months after sowing, it is necessary to thin out the seedlings and move them to the planting-out beds, which need not be in permanent shade, where they should be planted at intervals of 18 to 24 inches. Protection from frost in the winter and from the rays of the sun during the months of extreme heat will be needed.

283. Seedlings should be at least two years old before they are planted out. The holes on the road should be dug during the winter for trees that will be planted out in the rains, and in March they should be half filled with leaves. They should be circular and measure 4 feet at the top, 3 feet at the bottom, 3 feet in depth. When the trees are being planted, one only in each hole and that a plant with a single erect stem, the leaves should be drawn away so as to make a clear space 3 feet deep by 2 feet in diameter, which should be filled in with earth in which the roots of the tree should be planted, the transplanting being done during rainy or cloudy weather, or late in the evening.

284. The soil in which the trees are planted should not be much above, and certainly not below the surrounding soil. They need pro-~~tection and~~ many forms of tree guards are used of iron, of wood, of brick, of thorns, of cactus, but none are simpler and more effective than a ditch and wall or earth, the ditch being circular, of six feet outer radius, $2\frac{1}{2}$ feet deep, 2 feet wide at the top, and 1 foot wide at the bottom and the wall being of 4 feet outer radius, $2\frac{1}{2}$ feet high, 2 feet wide at the bottom and 1 foot wide at the top. Some babul thorns should be stuck into the top of the wall while the earth is wet. When the plant is old enough, this earthen wall can be cut down and the ditch filled up.

285. After planting special care is required to see that the young trees are sufficiently watered, especially in seasons of drought. A very effective method of applying water to a tree is to keep a deep narrow "*ghara*" buried close to its roots full of water, a system that avoids waste and the danger of overwatering and admits of easy inspection. The surface soil for 12 inches all round the trees should be kept as loose as possible, and in localities where frost occurs, the trees need to be protected during the first two seasons by means of thatching grass tied round each, which should be removed as early as possible to enable the trees to get the benefit of the sunshine.

286. Trees that are not growing straight should be attended to while they are quite young, and be tied with soft unspun hemp fibre or some

similar material (not cord or string) to a straight vertical stick fixed near the root of the tree. If trees are planted early in the monsoon, any that prove to be failures can be replaced at once by other plants from the nursery; but in the case of those that are planted late in the season replacements cannot be made till the following year.

287. Lopping is best done at the end of the cold weather (February) or of the rains (September) with a saw, not a hatchet as close to the trunk or main branch as possible, no stumps being left and a small cut being first made below the branch which is being lopped, so as to save tearing. The surface of the cut should be smeared with resin or tar. Fallen trees, felled trees, loppings and produce of the trees should be sold by auction. Care should be taken to see that camel drivers and villagers do not damage trees by breaking off any branches for their camels and goats. It is well to keep a register of, and watch the growth of, all young trees carefully, removing from the road any malis who neglect their work.

CHAPTER XI.

EARTH ROADS—TEMPORARY ROADS—BRIDLE ROADS.

288. Earth roads are very frequently made in India. In fact the majority of district roads in the United Provinces are earth roads, unbanked, or banked, as the case may be, sometimes bridged, sometimes unbridged. In some cases the travelling surface is divided into two parts by an earthen wall, one side being reserved for light traffic and one for heavy traffic ; but, as a rule, the section of the road resembles that of a metalled road without the metal, if the road is one that may eventually be metalled. Otherwise it is narrower. Some roads meander over the country, others are mathematically straight for miles. Some are carefully laid out and have a good surface throughout their length, others are spoiled by short lengths of indifferent surface and would be much improved if these short lengths were taken in hand and put right. As a rule, the grants for the repair of earth roads are small and sometimes they are not spent to the best advantage.

289. In America earth roads are in great evidence, as over 90 per cent. of the roads of America, or 20,00,000 miles, are earth roads and American road literature is full of the names of special appliances for the creation and preservation of earth road surfaces, such as road drags, ploughs, drag scrapers, wheel scrapers, road graders, elevating graders, for descriptions of which reference should be made to such works as Blanchard's "Elements of Highway Engineering," or Baker's "Roads and Pavements," or Byrne's "Highway Construction." None of these machines is regularly used in India where, as a rule, all the works is done by means of digging tools ("*phaurahs*") and baskets, or wheel-barrows, as described in the College Manual on Earthwork.

290. A point to which attention should be paid in the construction and maintenance of earth roads is the drainage. Sub-drains are seldom used in India, as the natural water surface is usually far below ground level, but there are places where it would be useful, for in some localities the water level is very near the natural surface of the country and road banks are permanently moist. As regards surface drainage, it may be said that this depends on the longitudinal grade, the crown of the road and, where the road is not in bank, on the side ditches. *See* also paragraph 296.

291. It is interesting to note in this connection what the American practice is. In America earth roads are not always banked, but are often cut out of the surface of the ground by means of special appliances which

cut the side ditches and throw the earth towards the centre of the road where it is shaped to a proper section. This section and the ditches may vary with the longitudinal slope, wide deep ditches being allowed for grades under 1 in 50, smaller ditches for grades under 1 in 25, and paved gutters for steeper slopes, the crown of the road being as much as 1 in 12. This should be considered the maximum cross-slope for any earth road, and, as a rule, the cross-slope allowed is half this or 1 in 24. As regards longitudinal grades, Baker in "Roads and Pavements" says that in Hilly country short grades of 1 in 3 are occasionally found and grades of 1 in 4 are somewhat common, while in comparatively flat country grades of 1 in 8 are not infrequent, but Blanchard in "Elements of Highway Engineering" says that, if practicable, the longitudinal grade should not be over 4 per cent. and under no conditions over 6 per cent.

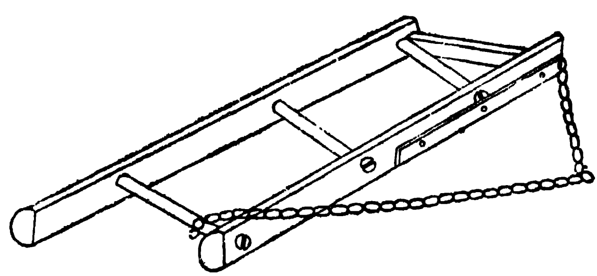
292. In India for earth roads in tolerably level country a maximum grade of 1 in 20 should be adopted. The co-efficient of friction on a good earth road is said to be $\frac{1}{10}$, and a reference to Tables I. and III., paragraphs 44 and 47, will show that if in the former a load of 1·00 can be drawn on the level, in the latter with double the exertion this can be drawn up a slope of 1 in 20, the co-efficient of friction in each case being $\frac{1}{10}$, and this indicates roughly that, with reference to the load that can be drawn on the level, the maximum grade on an earth road may be 1 in 20. Increase the draught power and the load can be carried over a greater gradient, but it is awkward to supplement animal draught power whenever a steep slope is met with, while, at the same time, it is not economical to have excess of draught power on the level. So 1 in 20 may be taken as a good maximum working grade on an earth road, unless the soil is of a kind that will cut up easily as water flows down it, in which case an easier grade must be allowed. For short distances, say, half a furlong, 1 in 10 may be admitted on some earth roads carrying wheeled traffic; but there should then, if possible, be a corresponding adjacent length of 1 in 25.

293. Some soils cut up easily, others get very slippery, so it is not possible to prescribe a definite gradient and crown for all; but if an earth road is made with a maximum gradient of 1 in 20 and a maximum crown of 1 in 24, it ought to meet all average cases. The roads in India are generally banked when they are not mere cart tracks, and cannot be made by means of American graders, etc., but for repairs a split log drag might prove useful.

294. A split log drag consists of two halves of a log about eight feet long and 10 inches in diameter split as nearly in half as is practicable,

The two halves are braced together as shown in the sketch, an iron strip being fixed at the outer end so that its outer edge projects about half an inch below the log, while the inner edge is flush with the lower edge of the slab. A chain is fixed to the front half log, one end being attached to the middle of the outer end of the slab and the other end being passed over the top of the log and attached to a brace. Over the braces is fixed a platform for the driver. As the drag moves forward each from the outer edge of the road passes below the chain as it runs along the log towards the centre of the road.

Fig. 45.
Split log drag



295. As a rule, the allowance for the maintenance of an earthen road in India is small and can be misspent on small repairs all along a road. It is better, on the whole, to concentrate on repairs, taking up a small portion of a road and improving it by means of efficient repairs. Permanent road gangs are seldom found on earthen roads and very often repairs are done at a time when nothing but dry earth is obtainable, which soon turns to dust and is blown away by the strong winds of March and April. It is advisable to carry out surface repairs towards the end of the monsoon where wet soil is obtainable which, when filled into the cart tracks, sets firm and gets covered with grass before the heavy winter traffic tests the repairs. Side slopes may have to be repaired after the monsoon, for they suffer damage during rain.

296. Attention to drainage is very necessary on earthen roads, and it is only by maintaining the shape of the cross-section that the surface can be properly drained. Sub-drainage is usually carried out by laying a line of earthenware pipes about 5 feet below the surface of the ground under one or both of the side ditches. The size of the pipes and their slope depend on the quantity of drainage that may have to be disposed of, and sometimes the pipes are laid in trenches filled with broken stone or small boulders. Two lines of pipes are not really required,

for one line on the "up-stream" side of the road can do all that is needed.

297. For other matters concerning maintenance, the chapter on maintenance should be consulted.

298. Temporary roads have sometimes to be opened out across a river bed or before permanent metalled roads can be made, or while metalled roads are under repair, and may be of various kinds. There is, for instance, the road that has to be made across the sandy bed of a river near a boat bridge. In this case funds may admit of the use of sections of wooden trackways (made of "*sal*" wood as a rule) in six-foot lengths tied by cross pieces and placed end to end to form the roadway for wheeled traffic, with crossing stations at suitable intervals. These short lengths can be put in position after the monsoon and removed when the next monsoon approaches. The track under each wheel should be 2 feet or more in width, as country carts swing about as they advance and narrow treads will give trouble. If a wooden trackway cannot be provided, the road must be made of bundles of "*jhao*" (tamarisk) or long grass, about six inches in diameter, tied with string and placed side by side in a trench, say, 12 feet wide by 12 to 18 inches deep, over which should be thrown clay 12 inches to 18 inches deep well beaten down. On the surface of the clay a thin layer of loose grass should constantly be maintained. Such a road would not last more than a season, but it would not cost much, and it would save draught cattle the toil of struggling through heavy sand. A somewhat similar road can be made for the use of the traffic when a road diversion is necessary during the construction of a bridge or other work or during repairs.

299. Dry sand interferes much with traffic. Wet sand, on the contrary, makes a fairly good roadway and heavy carts travel comfortably across stretches of wet sand on a seashore, provided there are no quicksands. Sometimes it is clay that has to be dealt with. Clay, when dry, makes as good a fair weather road as wet sand does, but when it is wet, it is easily cut up by the traffic and converted into a quagmire. Sand over clay helps to improve matters, and an example of a road improved in this way is given in the College Manual on Roads, 7th edition :—

"Portions of the unmetalled road between Prome and Porseday in Pegu were formerly impassable during the rainy season, owing to the soil being very clayey. The officer in charge of this road suggested the application of a layer of sand in lieu of metal, as the latter was not, in that locality, obtainable, and the experiment was sanctioned. He reported that the sand, which was laid down before the rains of 185[illegible], was

in the dry weather ~~rather heavy~~ for wheel traffic, but during the rains was as hard as possible and enabled carts to traverse the road in question throughout the monsoon, which they had never previously, in any numbers been able to do. The road had sustained little damage from the rains of 1859, and the sand had so mixed up with the original soil, that the surface of the road had become quite hard and carts passed to and fro without suffering in the least from heavy draught. The expense of repairs had been very trifling, though the road had been much cut up by heavy traffic. The ruts formed filled up on the occurrence of the first heavy shower of rain and the road again became hard. This experiment proved successfull."

300. Sometime a temporary road is carried across a "*jheel*" or shallow lake. This may have a solid bottom or may be spongy and soft. It may be still water or have a current. If it is still water at normal times, it will nevertheless require a culvert in the embankment to balance the level of the water on both sides, as the water level rises after rain or falls as it is drawn off. If it has a current, it is part of a stream and the bank must be provided with a culvert. If the soil is hard and firm, the bank may be made of earth. If, however, it is marshy and spongy and compressible, it may be necessary to throw in brushwood or bags full of clay or sand or stones in order to form a foundation for the bank. This is usually necessary also when a bank is being formed in a strong current. Temporary culverts in a temporary bank can be made of "*ballis*" of sal wood driven well into the ground and backed by bags full of sand or stones. These form the abutments. "*Ballis*" may also be used as joists ~~and railings, the flo~~oring being of bundles of tamarisk or of grass covered with clay and grass. The abutments can be protected from scour by sand bags or bags full ~~of stones~~.

301. In the hills temporary roads consist of a narrow road excavated in the hillside either for foot traffic or for pack animals, and for such roads nothing special is wanted beyond retaining and breast walls, except where cliffs must be negotiated or streams crossed. Usually cliff faces are avoided by going over them at a steep grade and streams are negotiated by crossing them by simple bridges at favourable points, but sometimes a cliff face cannot be avoided and a cliff gallery has to be made or the road has to be carried through in a half tunnel cut out of the hillside. For narrow galleries jumpers driven into the rock face and carrying three or more *sal* "*ballis*" or pine logs lashed to them by wire may be used, the jumpers being driven in at distances apart which depend on their strength and that of the "*ballis*" and the weight they

carry. Over the "*ballis*" cross-planks form the roadway. For a wider cradles would have to be anchored to the rock, or suspended by road wire ropes from jumpers driven in higher up the cliff face, beams being laid from cradle to cradle to carry the cross-planks of the roadway.

302. A full description of a cliff gallery and of the subsequent substitution of a roadway blasted out of the solid rock is given in paragraphs 81 to 83 of the College Manual on Roads, 7th edition, which are here reproduced as being of interest to the road engineer :—

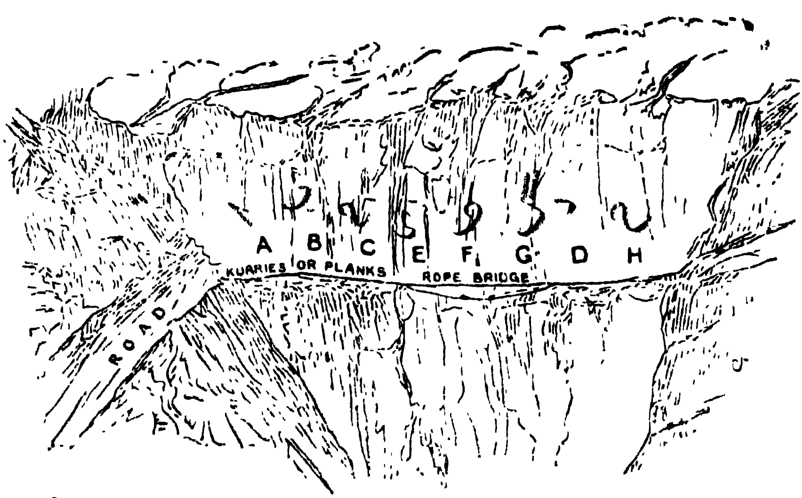
"81. *Cliff Galleries.*—By reference to Figs. 46, 47, 48 the construction of a *Gallery* (as this kind of work is called) will be readily understood. It is supported by cradles at, say, 20 feet apart. These cradles are each composed of either three or four iron bars or jumpers J, J (according to the breadth of the cradle) let into the face of the cliff at an angle of about 45°. The jumpers should have a fair hold in the cliff of at least 2 feet or 2 feet 6 inches, and a projection from the face of the cliff of about 2 feet 6 inches or 3 feet. They carry a wood stanchion cap Q, which is secured by large spikes to the heads of the stanchions, which are for this purpose "upset" and flattened at this part. In the angle between the iron stanchions and the cliff a heavy block of wood, the cradle sill block B, is securely jammed. Into this are footed, by mortise and tenon joint, the posts P and struts S of the cradle : and on the heads of posts and struts are jointed the cap pieces C : the cradle is strengthened by bracing pieces T, tying cap, post and struts together. The ends of the caps nearest to the cliff are tied into the cliff by iron bars or straps A. For ordinary purposes, when the gallery passes along the face of the cliff, the section and scantlings, etc., as shown in the drawings will be ample, and it is only in such cases as a recess in the rock, or where a pier for a bridge is required on the face of the cliff, and the road inclines to it at an angle, that any modification of the example given is necessary. Such modifications as these can, of course, only be determined from an examination of the spot. All stirrups and horizontal cap pieces connecting the heads of the struts with the upright posts should be secured by iron straps or bands let into the cliff and secured by lead.

The cradles may be put up at convenient distances apart, there being no necessity for adhering to exactly the same spans for the bays, provided that the distance be not so far increased as to necessitate too heavy scantlings for the roadway beams spanning the spaces between them, and by varying the distances advantageous spots for the construction of the cradles may be secured or disadvantageous ones avoided. For a 6-foot road there should be three girders which may either be placed

the same distance apart, or the two inside ones placed closer to each other; for on the face of the cliff it will be found that decay will set in earlier in the inside one than in the outside one, on account of dripping water, etc., and it should always be an object to relieve it as much as possible of weight. The planked roadway should have a sprinkling of fine gravel thrown on to it; but as this is not always to be procured in the hills, a very thin layer of fine broken stone mixed with earth should be spread. If the gallery is not constructed with a uniform level throughout, but undulates according to the facilities or rapid construction offered by the cliff, thin strips of wood should be laid across, before having the earth spread, so as to render traffic more secure in wet weather.

82. The crossing decided upon for the construction of a gallery across any cliff should be the one that contains the greatest number of broad natural ledges of a few feet in width as the work can then be completed to each one of these ledges, thus forming a roadway for the transport of materials to the portion of cliff beyond. Having selected a line for the gallery as A, B, C, etc., the next operation will be to set men to work to fix the jumpers from which to suspend ropes and planks. The first thing to be done is to get a good cliff climber to get out to A, where a hole will be bored in the cliff and a jumper let in. To effect this, he may be lowered by ropes from some accessible point above, or armed with a hammer and long spikes he may work his way, driving in spikes for a foothold, to some tree or projecting crag on the cliff, where he can get a more secure spot for driving in a jumper. The cliff climber will then endeavour to get to B, and repeat the operation, and so on with C. Between these

Fig. 49.



jumpers, and resting on them, a *kurrie* will be placed. The kurries are

lashed to the jumpers, and workmen lashed to the kurries on which they are seated while drilling holes into the rock. If the first points, such as A or B, are above the true line, ropes will be attached to the jumpers at A and B, and planks suspended therefrom: on to these suspended and swinging planks the workmen will be ~~lashed.~~ But, supposing, there are 50 or 60 feet of smooth perpendicular cliff in advance of C on to D, then the cliff climber will scale the cliff to get to a place where there is standing room at D. At this point another bar will be let in, and a rope bridge suspended between these two points will enable men to be set to work to bore and let in bars at E, F, G, while the bar H will be secured at the same time; and thus a temporary line of communication will be opened across this portion of the cliff, and in advance of H the same operation will go on. Though this is an exceedingly dangerous operation, there are few good cliff climbers who pride themselves on their activity and powers to climb to apparently inaccessible places, that will ever hesitate to go wherever they can hang with only their fingers and toes: and when once the temporary foothpath, from 4 to 10 inches wide, is opened across the cliff, an officer can go and select the sites for the cradles. In some places perhaps *kurrie*, cannot be laid and it will be necessary to lower or raise oneself by a rope secured to an iron bar let into the rock some height above the proposed level of crossing. Great care must always be exercised in crossing this temporary footpath, for it not infrequently happens that there is a sheer perpendicular drop of 500 or 1,000 feet below.

83. Such galleries can be expeditiously constructed and enable communication to be opened rapidly across long stretches of precipice, which would bar the progress of a more permanent road for many years. They are consequently invaluable for the first opening out of a new road; but they should be regarded as only temporary expedients, to be eventually replaced by solid walling or blasted out half tunnels.

The following description refers to the substitution of roadways blasted out of the solid rock for the wooden galleries that were first erected on the Hindustan and Thibet road.

The Rogi cliff being the most difficult on the line, it was determined to commence with it first. The altitude of the roadway on this cliff is about 9,500 feet above sea level.

Fortunately, from the method adopted in first constructing galleries along this cliff, there were above the level of the gallery several holes bored for holding jumpers, from which ropes were at once suspended; and men were set to work to bore as many more holes as were necessary to suspend sufficient men for the proper working of the cliff. Thus we succeeded in getting in a row of jumpers from which to suspend the men; we crowded as many as possible on the work. The total length of this cliff in hand at the

same time was between 300 and 400 feet, on the face of which from 400 to 600 men were suspended for a period of nearly four months. the number gradually decreasing as the roadway was worked out.

The Rogi cliff is of very compact gneiss. Its lamination is found in every direction, being either horizontal, circular, vertical or oblique. The most provoking part was that for a long time, work it as we might, nothing but continual scaling occurred, which was trying to both temper and patience. It was certainly a magnificent sight to sit opposite to the cliff and watch these men working with apparently as much ease as if they were on a 6-foot roadway. But how much indeed depended upon the ropes on which they were suspended, for as many as fourteen men were sometimes on one plank, and we were not overabundantly provided with rope to supply the place of pieces considered unsafe. Along the proposed level of roadway a row of crowbars was sunk, on which a kurrie or plank footway rested so as to allow of our crossing to inspect the work, as well as to enable the men to go backwards and forwards. This footway was never wider than the breadth of a plank, and very frequently not wider than the breadth of a kurrie. Every day the direction at the mines had to be altered according to the result of the previous day's work, and as a rule, nearly every yard in length required a different treatment.

Where scaling went on, it was necessary to abandon any attempt at tunnelling or scooping out, and to cut down from a height of about 20 feet. The first mine by this arrangement generally produced a little scaling, another sunk immediately behind increased the line of least resistance; and after two or three mines were fired, scaling may be said to have stopped, and small mines and weak charges were then resorted to.

In places where the lamination was horizontal, the scooping out or half tunnelling commenced from near the level of the roadway upwards. But it was not always that the effect of the mines on the cliff could be noticed; and as might be expected from the nature of the cliff, many mines were fired without the slightest result.

Our charges for blasting in ordinary places were $\frac{L\ L\ R^3}{15}$ = charge in lb., but as it was desirable that every stone disturbed in the cliffs should be got rid of, so as to reduce the necessity for the use of crowbars, which in many places could not be used, and in others not without the risk of their falling on one of the workmen, the charges were increased to $\frac{L.\ L.\ R.^3}{10}$, which worked with excellent effect, splitting the gneiss generally into small blocks, and throwing them clear of the work.

The result of experience on the Rogi cliffs is, that it is always preferable to work from a certain height above the level of the proposed roadway, not only for the purpose of tunnelling out, but because the men are so much sooner able to obtain a footing on the cliff. This plan of cutting from a height of about 20 feet above the proposed level of roadway has been tried with excellent effect upon the Maizong and other cliffs, and is now generally adopted in all the rock cuttings.

The blasting on the Rogi cliffs cost on an average Rs. 20 per running foot for the whole of the cliff; but there were portions that cost over Rs. 40, whilst the average of the Maizong cliff, of the same material, but differently stratified, was Rs. 12 to Rs. 15 per running foot. On these cliffs there were a few places where the cost was about Rs. 30 per running foot. By cubic measurement, the cost of blasting on the cliffs was nearly Rs. 15 per 100 cubic feet, and the walling from Rs. 5 to Rs. 8 per 100 cubic feet."

303. The College Manual on Roads, 7th edition, says that the maximum gradients for certain roads should be—

Foot Path for coolies, ...	1 in 5
Bridle Path, ...	1 in $7\frac{1}{2}$
Mule Road, ...	1 in 10
Camel Road, ...	1 in 15

but the average gradient should be—

Foot Path for coolies, ...	1 in 7½
Bridle Path, ...	1 in 10
Mule Road, ...	1 in 15
Camel Road.	1 in 20

and the Military Works handbook prescribes—

(*a*) For a mule road :—

Ruling gradient 1 in 7 with a maximum of 1 in 5 for lengths of 200 feet or 1 in 6 for 300 feet, provided that corresponding and adjacent lengths have grades of 1 in 9 and 1 in 8 and the total rise in a mile is less than 750 feet.

(*b*) For a camel road :—

Ruling gradient 1 in 10, with a maximum of 1 in 8 for short lengths less than 400 feet, provided that a similar and adjacent length is 1 in 12 and the rise per mile is less than 500 feet.

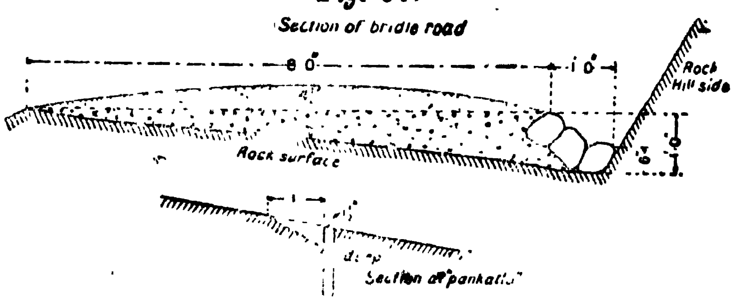
304. It is seldom that roads are built for one form of a traffic only, as mules or camels. The engineer is usually asked to design (1) a cart road for camels and country carts and ekkas, which may later on be converted into a metalled road for tongas or for motor cars, or (2) a bridle road for foot passengers and ponies and mules, and he will get a very comfortable bridle road, if he adopts a grade of 1 in 10 and can so arrange as to keep the rise per mile under 500 feet. For short lengths of 400 feet grades of 1 in 8 may be admitted, provided that there is a similar and adjacent length with a grade of 1 in 12. Many bridle roads have steeper grades than these, and, if funds will not admit of the use of easier grades, those given for a mule road in the Military Works handbook may be adopted.

305. It used to be the fashion to make all bridle roads with an outward slope, and if funds are very scarce or if a road must be made quickly, this method of forming the road surface may be adopted ; but the road cannot be expected to be kept in good order for very long without much attention. If the outward slope is made out of the original rock of the hill side and covered over with good soil, this soil will soon be washed out and the result will be that a very uncomfortable and dangerous travelling surface will be left. Even if the road is formed with an outward slope by excavating the rock to an inward slope of 1 in 10 over which good soil is filled in, the road will require a great deal of maintenance. The proper section for a bridle road is the section with a crown and an inner drain from which the water is led away through scuppers and culverts. This section was adopted by Mr. H. J. Oliphant, Executive Engineer, Kumaun, and Mr. O. Olliff-Lee, District Engineer, Naini Tal,

and found to be very successful in practice. In making a road of this section, the rock of the hill side should be shaped to an inward slope of 1 in 10 in a width of 10 feet of which 1 foot is reserved for the drain and 9 feet for the travelling surface. The drain having been formed, stones of about $1\frac{1}{2}$ inches and earth are laid over the rock surface and brought up to a level with the outer edge of the road. Over this filling smaller stones and soil are laid to a width of 9 feet and a crown of $4\frac{1}{2}$ inches, which gives an average slope of 1 in 12 from the centre towards the edges. A high crown is not good for a road, since it tends to bring all the traffic to the centre of the road and makes the margins of the roadway dangerous, but if the $4\frac{1}{2}$-inch crown is found to be too small for the drainage, it can be increased to some extent, say, to 6 inches.

306. This section is for a road without parapets. Where parapets are necessary, the road excavation should be 18 inches wider, the travelling surface being kept at 9 feet. With a $4\frac{1}{2}$-inch crown the road surface should not need what are known in India as "*pankattas*" (water-cutters), but if these are found necessary, they should incline from the centre towards each edge of the road at 45° and be placed at suitable distances apart such as the square of the gradient, *e.g.*, 100 feet for 1 in 10. They should be of stone $1\frac{1}{2}$ inches thick, sunk into the road to a depth of not less than 12 inches and with their top edges level with the surface of the road. The road surface on the upper side of the "*pankattas*" should be slightly dug out.

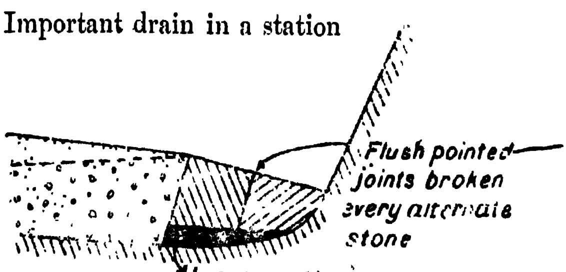
Fig. 50.



307. The inner drain of the road can be made in several ways :—

Fig. 51.

Important drain in a station



CLIFF GALLERY.

Elevation and Section.

Scale—8 Feet to 1 Inch.

Fig. 46

TRANSVERSE SECTION OF CRADLE AND ROADWAY ABOVE IT.

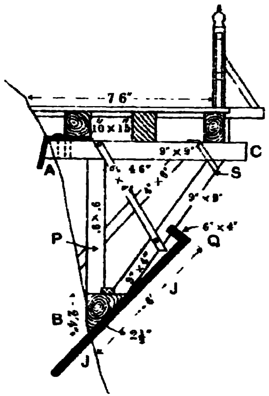
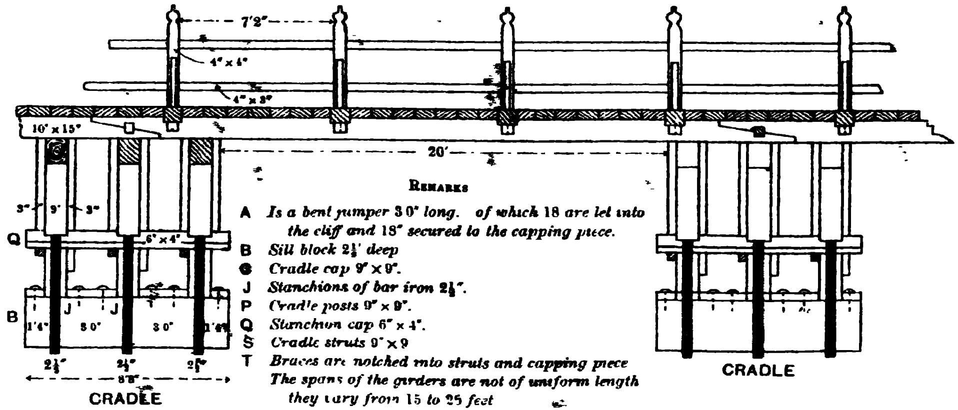


Fig 47.

ELEVATION OF TWO CRADLE PIERS AND INTERMEDIATE BAY



Remarks

A *Is a bent jumper 3 0" long. of which 18 are let into the cliff and 18" secured to the capping piece.*
B *Sill block 2½' deep*
C *Cradle cap 9" x 9".*
J *Stanchions of bar iron 2½".*
P *Cradle posts 9" x 9".*
Q *Stanchion cap 6" x 4".*
S *Cradle struts 9" x 9*
T *Braces are notched into struts and capping piece*
The spans of the girders are not of uniform length they vary from 15 to 25 feet
And as a rule 18 or 20 feet are found the most convenient spans

Fig 48

DIAGRAM OF GALLERY RUNNING ALONG THE FACE OF A CLIFF

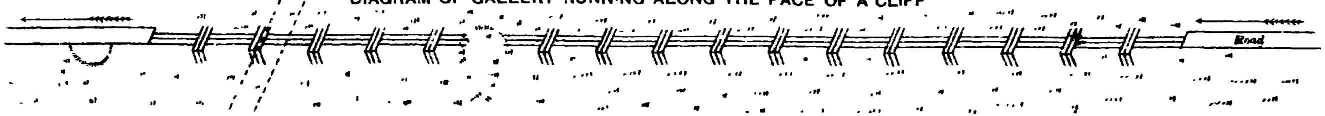


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Fig. 52.

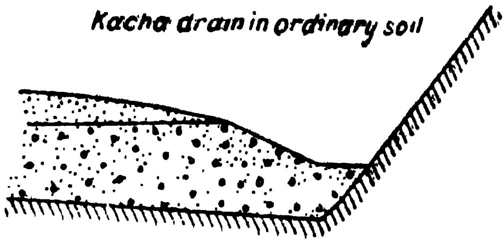


Fig. 53.

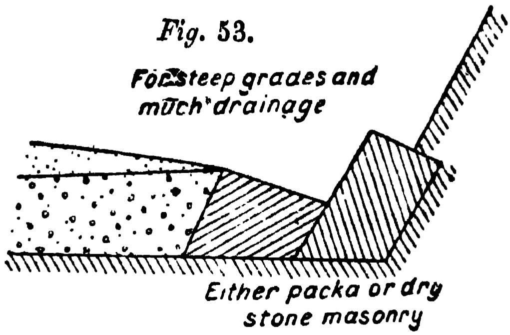
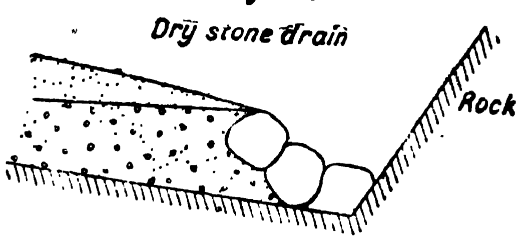


Fig. 54.



308. Parapet walls for bridle roads are generally made of dry stone masonry in short lengths with spaces between them to pass the outward drainage, or large rocks are arranged to form a parapet, or wooden railings are used, or reinforced concrete posts with horizontals of strong wire. Wooden railings are a mistake for travellers, convert them into firewood, or they rot and become dangerous. Wire breaks and sags when coolies rest their loads on it, and it cannot be replaced easily in out-of-the-way places. On the whole, stone parapets are the best, but they need to have a coping of stones in lime mortar or of reinforced cement concrete, or the stones will gradually disappear.

309. Scuppers should be placed in firm soil whenever this is feasible. They should be spaced at small intervals and can be very cheaply made by cutting a channel 18 inches wide in the rock and putting slabs over it,

All culverts should have catch pits on the up-stream side and their floors should be protected with reinforced concrete slabs if they are likely to scour out. Stone culverts are the most suitable for places where good stone can be found, but reinforced concrete can also be used, and with it bridges of considerable span can be built. Sometimes it is necessary to put up suspension bridges on footpaths or bridle roads. A scientific suspension bridge with stiffened girders is the best; but these cost money, and it is often sufficient to build suspension bridges in which the roadway is carried on cross beams and two longitudinals supported by suspension roads held up by steel cables, the railing being a railing and not a stiffened girder. The cable anchors should be so placed that they can be inspected at any time. This can be done by allowing a passage in the anchor block for this purpose.

310. Repairs to bridle roads resemble those necessary for cart roads in the hills, except that there is no metalling to renew from time to time. Instead there is the constant replacing of "*bajri*" and soil on portions of the surface worn down by the traffic, and in this work a rake should play an important part, or the surface will get covered with larger stones than are required. To get the work properly done there must be well trained permanent gangs moving from one road to another mending the surface, clearing slips, attending to "*pankattas*," scuppers, culverts, and everything else that needs attention, as drains, retaining walls, breast walls, etc. They would not, ordinarily, repair retaining and breast walls, but they could bring to notice matters needing attention.

CHAPTER XII.

DUST PREVENTION AND MODERN ROADS.

311. Kankar roads and water bound macadam roads are great dust producers, and also macadam roads, especially those which have been made with a excess of binding or blinding material.

312 It is usual to lay the dust in large towns by watering the road surface, a very expensive and inefficient method of dust prevention and one that, more often than not, ruins the road, for in many places gentle sprinkling is not adopted, but, instead, the road surface is overflooded with water which helps the traffic to create mud ; thus damaging the surface and making more dust when the water dries off. "Bhisties" as a rule, sprinkle a road effectively, but the ordinary municipal watering cart pours the water out in too liberal a stream instead of in a spray.

313. In some places spraying is done through proper nozzles on a hose pipe attached to the hydrants of the town water-supply, the pressure being sufficient to produce a spray ; occasionally water carts are fitted with a hose and spray, or with a pressure pump which helps to produce a fine drizzle, but more often than not, the water reaches the road surface in a stream, spoils it for traffic while wet and does damage which is permanent, for it helps the traffic to wear away the road.

314. Sea water is sometimes used as a palliative, but the salt in the water produces a kind of mud that damages carriages, etc., corroding the metal in them, and though the road surface remains damps longer when sprayed with sea water than when sprayed with plain water, its surface suffers more, as the sticky mud produced tends to loosen the stones which are picked up by passing carriage wheels.

315. Calcium chloride, either dry or dissolved in water, has been used with some success as a dust preventive in damp climates, but its effects are temporary. It can be obtained in granulated form or in a solution which can be diluted as desired. About three-quarters of a pound per square yard of road are first used and, at intervals of two months, about half as much or a total of 3 pounds a year, but more is required in exposed situations. When applied wet the calcium is dissolved at the rate of one pound to one gallon of water, using about one-third of a gallon of solution per square yard of surface. It is clean and odourless and easily applied where a supply of town water is available for distribution through hydrants, but it cannot be used where water is difficult to get. Such compounds as "Akonia," "Lymanite," etc., which are patented solutions, give results resembling those of calcium chloride

316. Oils and oil emulsions are sometimes used to combat the dust nuisance and their effects are more lasting than those of chemical salts, but they are, nevertheless, temporary and the emulsions do not help to preserve the road surface from damage. Of oils those which contain the largest proportion of asphalt give the best results, such as the oil which California produces and which contains from 60 per cent. to 84 per cent. of practically pure asphalt. With this oil in such a climete as that of California, which has long hot rainless periods, it has been found possible to make roads, called petrolithic roads, by mixing about 4 gallons of heated asphaltic oil containing about 75 per cent. of asphalt with each square yard of sandy or clay soil loosened to a depth of 6 inches, the mixture being consolidated with a special roller with many projecting feet into a solid and smooth layer which is durable and dustless.

317. Petroleums with lesser asphaltic bases are obtainable from Baku, from Galicia, and from Borneo, and are mainly valuable for their volatile parts, but leave residuum which is good for road work after distillation has removed the naphtha, gasolene, illuminating oils, and other elements which would be bad for such work. Oils that have a paraffin base or a naphtha base are useless. They smell and do not bind, and create a slippery surface on the road. The residuum of an oil light in asphalt is best suited for road work when the distillation is done more slowly and at a lower temperature than is usual when the production of gasolene or illuminating gas is the main object. Petroleum residuum or fuel oil, as it is sometimes called, needs to be tested before use in order to ascertain if it contains 25 per cent. of asphaltum at least, and it will be better for use in road work if it contains 40 per cent. The amount of contained water should not be more than 2 per cent.

318. Oil was used on the surface of kankar roads at the Allahabad Exhibition in 1910, and at the Delhi Durbar in 1911, and full notes of the methods adopted are given in Appendix 2, which also contains a note by Mr. J. Mackeson, B.SC., A.M.I.C.E., Executive Engineer, on work done for the Bombay Municipality.

319. Oil emulsions are easier to apply than oils, for the emulsified mixture can be spread by means of an ordinary watering cart or a sprinkler or sprayer ; it can be put down in any weather, except during heavy rain, and its application does not interfere with the traffic. In the case of oil, the traffic has to be kept off the road for two or three days till all the free oil has been absorbed and care is required to preserve objects along the roadside from its effects ; and these difficulties have led

to the use of emulsions which soak into the road quickly, but some emulsions in which acids or alkalies are used produced dust, that is, irritating, and their use has been discontinued for this reason, and most engineers prefer oils to emulsions of oil. Of these there are many patented forms of varying merit and durability.

320. Oil gas tar or water gas tar, a by-product of the manufacture of carburetted water gas from the asphaltic residuum of Russian petroleum or other similar residuums, makes a good dust palliative, but does not stand heavy traffic or heavy rain. It can be applied cold, but is better applied hot. Being light it flows easily and is usually put on from hand sprinklers. Its results are only temporary.

321. Tar painting is the next step in dust prevention and it helps road maintenance too, for there is now little doubt that an annual surface coat of good tar gives increased life to a broken stone road. Before the advent of motor cars water bound macadam roads were all that could be wanted for ordinary traffic, provided they were well made. Motor cars increased the dust nuisance, being dust raisers, and caused deterioration of the roads. The former led at first to the use of palliatives chiefly composed of chemicals. The latter required something more, and it was found that annual tar painting, properly carried out, helped not only to lay the dust, but to keep the surface of water bound macadam roads in good order.

322. With the introduction of the motor lorry and the motor omnibus roads of tar macadam, and of asphalt, were found to be necessary in some places where the traffic was very heavy, and a tendency arose in England to adopt them even in places where the traffic was still comparatively light. Experience has shown that this is not necessary for on well made water bound macadam roads, carrying ordinary traffic, tar painting or spraying is effective if it is renewed yearly. There are, in England, many roads which carry nothing more than ordinary traffic, but in towns, the traffic will be heavy. Where this is the case, better road coverings than water bound macadam, tar painted or tar sprayed, must be adopted.

323. It is only in some of the larger towns of India, in which there are not great extremes of climate, that tar painting may be required or better road surfaces needed, since the traffic on district roads is not, as a rule, heavy, and the climate in many parts of India is against the use of tar.

324. Good tar properly applied is the best form of dust preventer and road saver in England when the traffic is not inordinately heavy, but it has been found useless to use any tar that is obtainable and to lay it on anyhow, for the tar, in order to do good to the road, must be the best.

possible, it must be laid in clear and warm weather on a clean and dry surface and in a rapid and thorough manner.

325. Tar is an indefinite term, for tar can be obtained as a waste product in the manufacture of gas from bituminous coal, and it can also be obtained from works manufacturing gas from oil, etc. The former may prove good for road work, the latter will not. Yet it needs an expert to tell one from the other or from a mixture of both. Even at coal gas works, the coal gas tar will vary with the class of retort used, the quality of the coal, the temperature of distillation, and methods of treatment generally. Distillation at a high temperature, which is favourable to the production of gas, produces a high percentage of pitch in the tar, and too much pitch in the tar renders it unsuitable for road work, for it will become brittle after setting and will be liable to be crushed into powder by the traffic. This powder is worse than the ordinary road dust. If the distillation is not carried far, the volatile oils which remain in the tar will be adversely affected by the atmosphere and will possibly cause disintegration of the road surface. The need, therefore, for very clear specifications is apparent, and the Road Board in England has laid down precise instructions about the quality of the material and the methods of using it. Their specifications and instructions will be found in Appendix 3.

326. Tar, as it comes from gas works, is "crude tar" and contains volatile matters that would be injurious and have, therefore, to be driven off in order to produce "refined tar." "Tarvia" is an example of a prepared refined tar which is much used in America. In England Clare's patent tar-compo "Improved Dustroyd," when tested by the English Roads Improvement Association in 1917 at Reading, was found to give good results. There are other patented compositions, but on the whole, tar, if it is of the right quality, is as good as any.

327. There are advocates for tar painting and advocates for tar spraying. For instance, Mr. H. T. Wakelam, M.I.C.E., etc., the County Engineer of Middlesex, speaking at the County Councils Association Road Conference in 1909, said that, as a palliative at relatively small cost, there was nothing, in his opinion, that could equal tar painting by hand, but the climatic conditions in England would not admit of tar painting being done by hand to a great extent, and the next best thing he had found was spreading with the aid of horse machines. This was not so satisfactory as hand painting, but they got a life very much longer from horse machine painting than they did from painting by mechanical spreaders. Mr. Dryland, A.M.I.C.E., the County Surveyor of Surrey, said

that there seemed to be a general consensus of opinion among Surveyors who should be the most competent judges, that what is known as application by hand is the most durable and effective. Mr. Thomas, M.I.C.E., County Surveyor, Buckinghamshire agreed that hand painting was very effective.

328. On the other hand, Colonel Crompton, R.E., said that with machinery the road was dried and brushed and subjected to a strong blast of hot air, which thoroughly cleansed the surface and left it in a state to drink in the tar, which practically disappeared into the road, very little being left on the surface, and roads which used to be coated by hand every year did not after this need an annual coat.

329. Mr. Stilgoe, M.I.C.E., City Engineer, Birmingham, said that as far as the great towns were concerned they could not think of waiting while tar painting was done by hand, because of the expense of watching and lighting. He was of opinion that when the tar was applied under pressure, it had a more searching effect and he felt certain that, where good results were obtained from tar painting, and he had obtained them, they had been due to the fact that the tar used had been boiled and refined in the process. If crude tar was used in the tar spraying machines, it would not give as good results as refined tar. Mr. Phillips, A.M.I.C.E., County Surveyor of Glamorgan, mentioned the case of two lengths of road which had been treated with tar. The first section was done by hand with gas tar, thoroughly boiled, and the work cost for two coats and sanding slightly under 1*d*. per superficial yard. Part of this length was of granite and part of limestone, and the former gave the better results, but in both cases the abatement of dust was attained. Subsequently, another section was tar sprayed by machine, and though this was carried out at a less cost, namely, about $\frac{3}{4}$*d*. per superficial yard for two coat work, it was not quite so lasting as that done by hand. In both cases, however, the trials were successful, and there is no doubt that the preserving effect which it had on the roads treated more than justified the expense, as the treatment added at least 12 months' life to the roadway.

330. Mr. Yabbicom, M.I.C.E., City Engineer, Bristol, described three methods of tar treatment of roads. In the first it was applied by means of a heavy traction machine travelling at about 2 miles an hour, the tar being sprayed over the surface of the road through nozzles under pressure, the surface having previously been brushed clean. As soon as the tar had been distributed, a thin coating of fine sharp sand was scattered over it, enabling the road surface to be used almost immediately,

The cost was about ·95*d*. per superficial yard. In the second case, the work was done by means of a portable hand spraying machine of simple design and easily worked by two men, but having the disadvantage of needing to be taken to the depôt frequently for refilling, or to be accompanied on the road by an ordinary tar boiler. The force of the tar, too through the delivery holes was scarcely sufficient to cause as much penetration of the surface of the macadam as is necessary where there is considerable wear and tear. The cost of the work was about ·58*d* per superficial yard. The third method was tar painting by hand. Far more tar was used in this process, the result was not so even, and the work was slow. The cost was about 1·41*d*. per superficial yard.

331. Mr. E. P. Richards, M.I.C.E., and Chief Engineer, Calcutta Improvement Trust, in a paper on "The prevention of dust in Indian City Roads and Streets" which was read at the All-India Sanitary Conference at Madras in 1912, writes :—

"About 95 per cent. of the total length of tar treated roads in Europe are found to be tar sprayed or tar painted."

*   *   *   *   *   *

"Tar spraying is nearly always superior to, and more economical than tar painting, and 90 per cent. of the above 95 per cent. of European tar treated roads are of tar sprayed macadam. Tar spraying can be done very successfully in India if the right plant, the proper tar, and correct methods are used."

*   *   *   *   *   *

"I am confident from observation here and in Europe that the high pressure tar sprayer is the best machine for India."

332. There are several forms of tar sprayers on the market, of which one of the best is said to be "Aitken's patent pneumatic tar spraying apparatus" by which the tar can be sprayed under sustained pneumatic pressure sufficient to cause penetration to a depth of one to three inches into the surface of a used macadam road. This is fully described in Aitken's "Road Making and Maintenance." It can be motor driven or horse drawn according to its size. Another machine is the "Tarspra" made in three sizes of 200 gallons, 700 gallons, and 1,000 gallons capacity each. Still another is the "Lassailly Johnston Tar road binder" which distributes hot tar by gravity flow.

333. Tar macadam is essentially a layer or layers of broken stone bound with tar which may be placed below the stone before it is rolled, or above it, or, again, may be mixed with the stone before this is laid on the road. The stone aggregate sometimes gives place to slag, or to refuse

destructor clinker, and some other suitable matrix will sometimes replace the tar. A further method, which is known as the Gladwell system, is to sandwich the stone between two layers of stone chips treated with "Tarvia."

334. The first method uses much material and requires more labour than others and it is seldom used. The second method of spreading the metal first and the tar over it, known as grouting, requires warm sunny weather. The stone is spread in a layer and lightly rolled when dry and has boiling hot tar poured over it from buckets, or by hand sprinkling, or from a pressure cart, the object being to grout the road stones after they are partially rolled. The surface is finished by spreading stone chips over it and well rolling the whole. The trouble with this method is that the tar, which flows easily when hot, runs down to the bottom of the stone layer and makes it difficult to secure uniformity in the matrix, with the result that the tar is liable to become troublesome and sticky in hot weather. The cold stones, too, serve to chill the hot tar which tends to peel off them.

335. The third method, that of mixing the stones and the tar as concrete is mixed, is the one that is usually known as tar macadam. The proportions of stone and tar may vary, the stone and tar specifications may differ, but the principle is always the same, that is, that the stone requires to be thoroughly dried by heat and the tar requires to be refined before the two are mixed together. The stones are sometimes dried on cast-iron plates 4 feet by 3 feet by 1 inch thick fixed about 2 feet above ground level and supported on 4½-inch dwarf walls of brick, provision being made by means of openings in the walls to allow the heat from the furnaces to circulate freely under the floor. The drying floors are about 24 feet by 20 feet in size and are roofed. Large coppers of 80 gallons each are placed at one end of the building, and in these the tar is boiled for two hours or more, any pitch or creosote oil required being added. The mixing is performed by spreading the stones in a layer about six inches deep on the iron plates, and when they are dry and warm adding the hot tar and turning over the mixture till every part of the material receives a coating of tar. In the road work is to be done in three layers eight or nine gallons of tar to a ton of stone may be used for the first and second layers, and for the third coat ten to twelve gallons of tar to a ton of material. The mixed materials are usually stacked in heaps and left for a few weeks to season.

336. The road foundation should be properly shaped and rolled before the mixed materials are spread on it. Sometimes two layers are

used, but often only one layer of tarred $2\frac{1}{4}$-inch or $2\frac{1}{2}$-inch stone is put down of a thickness calculated to roll down to about 4 inches, and after this has been rolled, a top layer of tarred $\frac{3}{4}$ inch stone sufficient to fill the interstices is spread and rolled, the surface being finished with a top dressing of fine grit. Further particulars about tar macadam will be found in Appendix 3.

337. Hand mixed materials appear, as a rule, to be stronger and to wear better than materials mixed by machinery, and many engineers arrange to have the mixing carried out under their supervision and orders; but it is also possible in England to purchase the materials ready mixed at the quarries. When this is done, it is necessary to work to very clear specifications. Many firms carry out work with their own patented specifications and guarantee to keep the surface in order for a fixed period.

338. The system of using tarred furnace slag was introduced by Mr. E. P. Hooley, County Surveyor, Notts, and patented as "Tarmac." This has been used extensively in large towns and gives satisfactory results on roads subjected to considerable traffic, including motor omnibuses and traction engines. It is expensive, as is tar macadam, and cannot be used economically where tar painting on water bound macadam will keep the surface in good order; but it justifies its use in many situations. The Company's works are at Wolverhampton and include a distillation plant for producing tar that will give the best results as regards binding and weather resisting properties. The slag, obtained from iron works close by, has a very rough surface, is porous enough to retain and hold the mixture, and has great strength. "Tarmac" is made in three gauges:—$2\frac{1}{4}$ inches (includes $2\frac{1}{2}$ inches to $1\frac{1}{4}$-inches), $1\frac{1}{2}$ inches (includes $1\frac{1}{2}$ inches to $\frac{1}{2}$ inch), $\frac{3}{8}$ inch (includes $\frac{3}{8}$ inch to $\frac{1}{8}$ inch), and is sent out from the works in the Company's own trucks for immediate use. The Company have two standard specifications:—No. 1 providing for the use of $2\frac{1}{4}$ inches, $1\frac{1}{2}$ inches and $\frac{3}{8}$ inch gauges; No. 2 providing for the use of $2\frac{1}{4}$ inches and $\frac{3}{8}$ inch gauges only. No. 1 specification, "Tarmac," should be applied in two layers, the bottom layer consisting of $2\frac{1}{4}$ inches gauge, the top layer of $1\frac{1}{2}$ inches gauge, each layer being separately consolidated with a roller of about 8 to 10 tons in weight. The surface of the top layer, after half consolidation, should be well sprinkled with $\frac{3}{8}$-inch material, so as to fill all the interstices, and again rolled to complete the consolidation and give an even and water-tight surface, being afterwards blinded with slag, or other suitable grit, at the rate of 1 ton to every 250 square yards of road surface. The

thickness of each coat for total thickness of $4\frac{1}{2}$, 4, and 3 inches would be—

For $4\frac{1}{2}$ inches	—bottom coat	$2\frac{1}{2}$ inches,	top coat	2 inches.
„ 4 „	„ „	$2\frac{1}{2}$ „	„ „	$1\frac{1}{2}$ „
„ 3 „	„ „	1 „	„ „	1 „

Tarmac is not likely to be much used in India on account of its cost.

339. Of late years it has been found possible to use properly-prepared refuse ~~destructor~~ clinker instead of stone or slag, and many good roads of this material have been made in Beckenham, Worthing, etc. The clinker at Beckenham is crushed, and the dust and small stuff having been removed, the remainder, in pieces varying in gauge from $2\frac{1}{2}$ inches to 1 inch, is thoroughly mixed with tar and allowed to mature in the open for three or four months when it is "freshened with more tar before being laid on the road in a 6-inch layer, which is consolidated to $3\frac{1}{2}$ inches under a 10-ton roller, a $\frac{1}{2}$-inch top dressing of small limestone $\frac{3}{8}$ to $\frac{1}{4}$-inch gauge being spread over and thoroughly rolled.

340. So far the improvement of roads by using tar has been considered. It remains to deal with the use of asphalt as a matrix. Asphalt is the solid form of natural mineral bitumen. Bitumen is a natural hydro-carbon mixture of mineral occurrence, widely diffused in a variety of forms from a light gas to a solid. Bitumen consists chiefly of two parts :—(1) petrolene, yellow and oily, and (2) asphaltene, hard, black, and brittle. An excess of petrolene in asphalt causes it to melt at a low temperature and renders it deficient in stiffness, while a large proportion of asphaltene causes it to be brittle and wanting in the plasticity and cementing power requisite for the production of a good pavement. Examples of bitumen are naptha, petroleum, maltha (which is soft and sticky at ordinary temperatures), asphalt (which is hard at ordinary temperatures).

341. Asphalt is found in many localities, of which the most important are Trinidad, Bermudez, California, Switzerland, and France. Trinidad produces lake asphalt, the crude asphalt being dug out from the famous pitch lake, and land asphalt, which is an overflow from the lake and is of a less plastic nature than lake asphalt. Bermudez produces lake asphalt, the crude material containing a much higher percentage of bitumen than the Trinidad asphalt contains. California produces, at Santa Barbara, both solid asphalt and natural fluid bitumen or liquid asphalt, otherwise known as maltha.

Switzerland at Val de Travers and France at Seyssel produce limestone impregnated with a low percentage of bitumen.

342. The percentage of bitumen soluble in carbon bisulphide is, roughly, as an average, in these materials :—

Locality.	Crude materials.	Refined materials.
Trinidad lake, soft, ...	34	52
,, ,, hard, ...	38	53
,, land, ...	38	52
Bermudez, ...	93	..
California maltha.	..	98
,, solid, ...	59	..
Val de Travers limestone, ...	10	..
Seyssel	8	..

343. The crude asphalt of Trinidad, Bermudez, and California, etc., is refined by heating it in kettles, or open tanks, till the water and volatile oils are driven off. The refined asphalt is black and hard and brittle, and is chiefly asphaltene, and is of no use for road work till it has been softened and made adhesive by the addition of such a flux as petroleum residuum or as maltha. The flux should partially dissolve the asphaltene and form a chemical union by solution. If it is a perfect solvent of the constituents of the bitumen, the adhesive qualities will be lacking, and if it is a bad one, the asphalt will retain its brittleness. The temperature of the refined asphalt is raised to 300°F., the oil, previously heated to the same degree, is added in the proportion required which may be 10 to 20 lbs. of oil to 100 lbs. of refined asphalt, the proportion depending on the quality of the oil, the hardness of the asphalt, the climate, and the purpose for which the asphaltic cement is required. The mixture is agitated for several hours with great thoroughness, and it is customary to agitate it also when in use for a certain amount of separation takes place when the melted cement stands at rest. The mixture is continually tested with a weighted needle to ensure a proper degree of plasticity, and when ready is used as a cement or matrix for binding stone roads as described below.

344. Roads made with a stone aggregate and asphaltic cement as a binder are known in America as sheet asphalt pavements or monolithic asphalt pavements. They consist primarily of (1) a foundation, a binder cost of broken stone and cement, and a wearing coat of cement and sand, or of (2) a foundation, a cushion coat of cement and sand and a wearing coat of cement and sand. All asphaltic pavements need a solid and firm foundation, preferably of hydraulic cement concrete laid in a 6-inch layer. This must be well set and dry before the asphalt is laid on it, for if this is not the case, the water in it will turn into steam and honeycomb the

asphalt, which will soon go to pieces under heavy traffic. Sometimes foundations of broken stone or stone sets are used, or the asphalt is laid on a sound surface of an existing road; but this is not recommended.

345. A binder coat consists of a 1½-inch layer, when finished, of 1 inch or 1¼-inch stone with very little fine stone in it; for an excess of fine stone needs more asphalt to coat it, and the larger stone gives a rougher surface for the wearing coat to adhere to. The asphaltic cement is the same as is used for the wearing coat, but it is mixed somewhat softer. The softer mixture tends to make the coat adhere to the foundation. It is heated to a little over 300°F., and is poured over the stone, also heated to 300°F., all this being done by properly arranged machinery. While hot, the mixture is conveyed to the work, spread uniformly over the foundation (which must be clean and dry) and rolled till it adheres firmly to the surface below.

346. The wearing coat consists of sand, asphaltic cement, and stone dust. The sand should be such as would be used for hydraulic cement mortar, sharp clean and ranging from coarse to fine. The stone dust may be made from limestone or any suitable stone. It is used to help in filling the voids in the sand in order to reduce the quantity of cement needed, and the amount required depends on the coarseness of the sand and the quality of the cement. The proportions of the mixture vary with the climate, the sand and the traffic. The ideal condition is that each grain is coated and all interstices filled without an excess of cement. The proportions may range as follows:—

Asphalt cement,	...	...	15 to 12	per cent.	
Sand, ...	...	...	70 „ 83	„	„
Stone dust, ...	...	...	15 „ 5	„	„

The mixed aggregate and the cement are separately heated to about 300°F. and then thoroughly incorporated, after which they are conveyed to the work and spread with iron rakes to such a depth as will give the required thickness when finished. This is usually 2 inches, but varies in practice from 1½ inches to 2½ inches. The compression in rolling is usually about 40 per cent. The consolidation can be done with hand-rollers to begin with, but a light stream-roller of about 6 tons is better, working longitudinally, transversely, or obliquely, to take out all inequalities, heated tamping irons being used to ram parts which cannot be reached by the roller. The surface can be covered with fine stone dust or Portland cement after the primary rolling to prevent the adhesion of the material to the roller and to improve the appearance of the surface. Rolling can be finished with a 10-ton roller, but often only the light

roller is used. The amount of rolling varies, but thorough rolling is necessary untill the roller leaves no mark.

347. The road should then be thrown open to traffic, which is good for the road, the idea being that it aids in closing the surface and retaining the volatile oils, and asphalt pavements do better under traffic than in unfrequented streets. Inequalities in the surface must be guarded against, for though asphalt may be considered as impervious to water, yet it rots where water accumulates, as in gutters near drinking fountains. Gutters which do not drain quickly should be of stone or brick or hydraulic cement concrete, and others should be painted with a coat of hot asphalt. Rolling should follow quickly on spreading or the asphalt will cool before the final rolling takes place, specially if a strong wind is blowing. Asphalt is a bad conductor of heat and can be carried long distances without cooling after being heated as a central depôt, but to save mistakes the temperature of the mixture should be taken before it is spread, for chilled cement will cause a weak spot in the road. To correct the chance of cooling by overheating the mixture will not answer, for excessive heat reduces the cementing quality of the asphalt, which will also be spoilt if the sand is overheated.

348. If in the road described above the binder coat is omitted and its place is taken by a cushion coat, the broken stone will not be required and the expense of maintaining separate plant for warming and mixing the stone and cement will be avoided. The process will be that of laying two coats of heated cement, sand, and stone dust over the prepared foundation. The under coat, or cushion coat, will be made of the same materials as the upper or wearing coat, but will contain more cement than the latter in order to join it firmly to the foundation. The extra cement would make the wearing coat too soft, but it makes the cushion coat elastic.

349. On the whole, the cushion coat is to be preferred to the binder coat, and indeed the terms "binder coat" and "cushion coat" are, in practice, both used to refer to what is here described as a cushion coat, though it would be best to use the term "binder coat" when a broken stone aggregate is referred to and the term "cushion coat" to describe a layer of asphaltic cement, sand and stone dust below the wearing coat.

350. Sheet asphalt roads, as described above, were more used in America at first than in Europe, but they are being more freely used in Europe now where at first rock asphalt roads alone were used. Modifications of sheet asphalt roads, (*e.g.*, Whinery's method, patented in America, of putting the dry heated stone over the foundation coat, spreading a

hot mixture of asphaltic cement and mineral grains over it, and then rolling with a 10-ton roller till the composition is forced into the voids and the stone compacted with a uniform surface) have also been tried in England, as have other grouting methods with binders manufactured from bitumen; but these are not to be recommended when better methods can be followed.

351. Success has attended the use of selected refuse clinker and asphalt at Hornsey, where Mr. E. J. Lovegrove, the Borough Engineer, has patented his method of work. This is done in one or two coats. The wearing coat is of fine clinker ⅛-inch gauge and less, with a pure bitumen matrix and finished to 1⅛ inches. The under coat is of ⅛ inch to ⅞ inch clinker with a matrix of pure bitumen laid to a thickness of not more than 2 inches. Sometimes the lower coat is omitted, the wearing coat being laid on the surface of the old macadam road after it has been cleaned and swept. The materials in either case are laid whilst hot, the bottom coat being consolidated with a steam-roller. The top coat is rolled crosswise with a 6-cwt. hand roller and longitudinally with a steam-roller until firmly consolidated. The traffic is allowed on five hours after the work is finished.

352. Pure mineral-rock asphalt is used on roads that carry very heavy traffic. As mentioned earlier in this chapter, it is obtained from limestones impregnated with natural bitumen. There are found also sandstones impregnated with bitumen, but they are not much used. The limestones may contain 6 to 20 per cent. of bitumen, but not all these can be used; for if the quantity of bitumen is small, the material has not sufficient binding power to sustain heavy traffic; and if the bitumen is in excess, the road becomes soft and wavy in summer. Limestone containing 8 to 10 per cent. of bitumen gives the most satisfactory results. The material is crushed to the size of walnuts and ground to a very fine powder in a disintegrator. The powder is heated to a temperature of 250°F. or more to dry it thoroughly, and is transferred quickly to the road in specially constructed vans, to avoid loss of heat in transit, and laid on a foundation prepared for it. This foundation should preferably be of hydraulic cement concrete and at least 6 inches thick, but it may be more, and it may even be reinforced if the traffic is very heavy. It should be firm and solid and dry, which means that the work should be done in dry weather, for if the foundation is not dry, the water in it will turn to steam and honeycomb the asphalt and ruin it. The finished depth of compressed mineral-rock asphalt should be 2 inches, so it should be spread to a depth of 3 inches on the concrete

foundation direct from wheel barrows, and raked over the surface of the concrete, consolidated by ramming with heated 10-pound rammers, smoothed while hot to an even surface with hot smoothing irons until the proper wearing surface is obtained, and rolled with a half-ton hand-roller till it is compressed to the required thickness. The surface is finished with suitable curved hot iron tools until it is quite cool and a light sprinkling of Portland cement is spread over it, a few hours after which the pavement is ready for traffic.

353. Sometimes a pavement is made of compressed bricks of asphalt. These are made of asphaltic cement and crushed trap or granite, in proportions which vary somewhat with the climate and the fineness of the stone used. The materials, heated and mixed, are moulded under very heavy pressure into blocks which are about 12 inches long, 4 inches wide, and 4 or 5 inches deep. They are laid in the same manner as brick and as compactly as possible, and soon become cemented together under the influence of the sun and the traffic and form a practically impervious surface. In the best work a concrete foundation is employed.

354. A variety of asphalt bricks known as Lithofalt consists of sure asphalt and a silica filler. These are made about the same size as ordinary bricks, but are not more than 2 inches thick and are moulded under a pressure of about 200 tons to a square inch. They are laid in Portland cement mortar on a concrete foundation and well grouted over the whole road surface with Portland cement grouting.

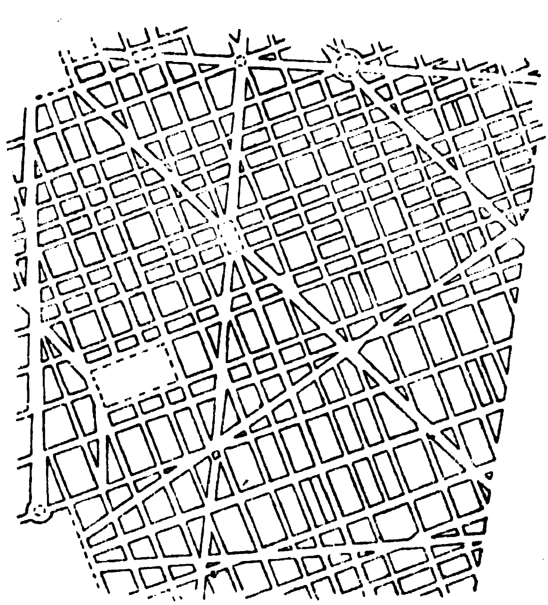
CHAPTER XIII.

STREETS, CARRIAGEWAYS, GUTTERS, AND SIDEWALKS.

355. In the arrangement of their streets towns seldom resemble each other; for the positions of streets in a town depend to some extent on the contours of the locality, curved streets being used in uneven country more than in flat land. Streets should, however, be arranged to give direct and easy communications, as far as possible, between various parts of a city, and this, it will be found, can best be done by the rectangular system with diagonal streets at intervals, the blocks being ordinarily long and narrow, and the diagonal streets radiating from public buildings or parks or business centres towards the suburbs, with boulevards perhaps at intervals.

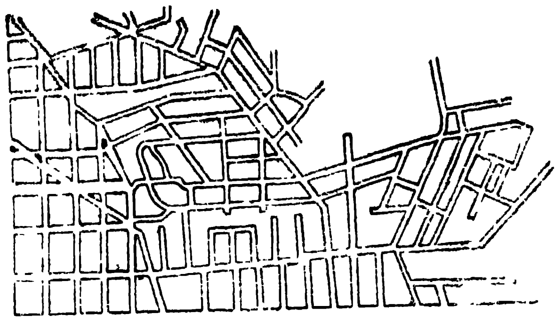
356. As a rule, it is impossible to lay out a town complete in every respect, and most modern towns have grown up from unregulated beginnings, improved and altered from time to time; but sometimes an opportunity occurs for plans to be worked out from the beginning and carried towards completion as the population increases. In such cases the experience of expert town planners can do much towards the preparation of an effective scheme.

Fig. 55.



Part plan of the city of Washington, paragraph 357.

Fig. 56.



Part plan of the suburbs of Washington, parrgraph 357.

357. The city of Washington is quoted as an example of a well planned city on a rectangular system, with diagonal avenues and open squares and circles at some of the intersections of the avenues. This is well illustrated by the sketch Fig. 55 on page 141. At the same time, there are, in the suburbs of Washington, short streets which form a labyrinth, and in some cases have practically no communication with each other. These are shown in the sketch Fig. 56 above and were made before the regulating laws were adopted.

358. The law now rules that all street extensions in Washington will conform to the general plan. No new street is to be less than 90 feet wide and avenues must be 120 feet wide. Streets must not be more than 600 feet apart, but intermediate streets, called places, 60 feet wide, are allowed within blocks. The blocks are of various sizes, a typical block being 600 feet by 400 feet.

359 The width of streets between building lines, which may be 60 feet to 90 feet in a residential district, does not of necessity determine the width of the travelling surface which depends on the present needs of the traffic. A width of 30 to 36 feet between kerbs is generally enough with a sidewalk on each side about 5 feet to 10 feet wide. The remainder of the width should be grassed if grass can be properly looked after, (if it cannot, it soon looks untidy) and tree spaces should be allowed between the sidewalk and roadway. In Lucknow some parts of new streets have been made 60 feet wide between building lines with 10 feet sidewalks and 40 feet roadway, trees being planted near the edge of the roadway, but the general width is less.

360. If the traffic is light, a roadway 20 to 24 feet wide will be found to stand a considerable amount of wear and where funds are scarce even smaller widths may be considered. A width of 20 feet is more than sufficient for two teams to pass each other.

361. In business districts where wholesale business is done and pedestrian traffic is light, the sidewalks can be narrow and the carriageway broad. Allowing 13 feet for a truck backed up against each kerb and 18 feet for passage room for two trucks, the width of roadway suitable for such business streets would be 44 feet. Where there is more pedestrian traffic, as near retail shops, the sidewalks should be given ample width. With ample width between building lines there will be room for increasing the roadway width if this is found to be necessary.

362. Wide streets afford a good amount of breathing space and add to the general health of the people, besides giving a city an air of spacious dignity and opening out views that would otherwise be lost. Narrow winding streets are picturesque, but do not add to the cleanliness, health, and comfort of a town.

363. In 1909, at the County Councils Association Road Conference, Mr. M. T. Wakelam, M.I.C.E., County Engineer, Middlesex, suggested a cross-section which allowed a central width of 32 feet for fast motor traffic inside and two lines of trams outside, 19 feet on each side for carriageways each separated from the central portion by a 4-feet width for lamp standards carrying three lamps, one over each roadways, and an edging of 10 feet to 18 feet on each side for paved footways with trees at the edge of the pavement. This gives a total width of from 98 feet to 114 feet—or the distance between building lines, but the 32-feet width for two tramway lines and two lines of carriages is small. An alternative section allowed for a central raised tramway track 19 feet wide flanked by carriageways each 19 feet wide and paved footways 10 feet to 15 feet wide, the lamp standards in this case being central and carrying two lamps spaced 19 feet apart. This gives a total width of from 77 to 87 feet. The disadvantages of the central raised tramway track are that it entirely separates two lines of traffic.

364. There are several advantages in having tramway tracks laid not centrally, but outside the sidewalks. The cost of construction and maintenance is usually less than when the roadway is used, the speed of travel can be greater, repairs can be done without disturbing the surface of the roadway, people can enter and leave the cars without inconvenience. A disadvantage is that these separate tracks interfere with the gradient of private carriageways from the roadway to houses along the road. Generally tramway rails are laid along the roadway centrally or at the sides, the tracks being made level with the pavement so as to interfere as little as possible with other traffic.

365. The construction of tramways is not dealt with in this Manual.

366. Streets in Europe and America are paved with broken stones, or cobblestones, or stone setts, or brick or wood blocks, or an asphalt surface, and when this is possible, the broken stone is painted with tar or set in tar. It is not always possible in India owing to the climate. Nor do wood blocks make a good pavement for India. Asphalt has been used, but it softens in great heat and is very expensive. Ordinarily the engineer in India will have to use kankar or broken stone, water bound, and he may adopt stone setts where they can be used or cobblestones where boulders are procurable. The last two would be used only where there was heavy cart traffic. Brick might be used in narrow streets without much traffic, and gravel where it is easily obtainable.

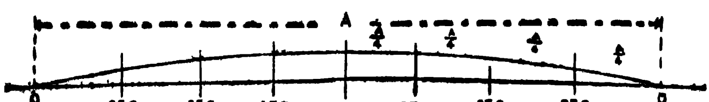
367. The construction of a good street pavement requires that the material used should be confined between kerbs, and it is usual to have a kerb and channel drain defining the edges of the road material, with sidewalks beyond. In this case the cross-section of the roadway may be a segment of a circle, or a parabola, or a composite curve, instead of being made up of two inclined planes rounded at the crown for the steeper marginal slope of the convex curved section fits in well with a kerb and channel drain.

368. The convex cross-section will vary with the material used and will be varied even for the same material by different engineers, but the general principle that is followed is that the crown should be less for smooth materials, as asphalt, than for rough ones, as broken stone, and less for an easy longitudinal grade than for a steep grade, but a perfectly levels road, Codrington says, may require a rather rounder section than a road with moderate gradients.

369. Baker in "Roads and Pavements" mentions that in Omaha the crown is decreased as the steepness of the road increases, "a method which," he says, "is commendable." The crown for asphalt in Omaha is greater than that for brick, stone block and wood block, and Baker remarks regarding this "considering only the smoothness of the surface it appears that asphalt should have the least crown, but considering only the fact that asphalt rots when continually wet, it appears that asphalt should have a large crown."

370. This is not generally accepted. The curve described in paragraph 105 as being obtained by the rule there given corresponds very closely with the standard section adopted in Liverpool and other towns in England, *viz.* :—

Fig. 57.



and in this section the crown C may be for asphalt $\frac{A}{45}$ for hard wood and granite $\frac{A}{45}$, for soft wood $\frac{A}{36}$, for macadam $\frac{A}{30}$, but these figures are not absolute.

371. Granite and syenite setts are suitable for the heaviest traffic and require very strong foundations on a good road bed. Cement concrete foundations are employed for the best work, and, as a rule, at least 6 inches of concrete is used. In determining the size of the setts, it should be noted that their depth determines the stability of the pavement; the width depends on the size of a horse's hoof in order to give a good foothold, and the length is influenced by convenience in handling. Granite or syenite setts may be about 3 inches wide, 7 or 8 inches deep, and up to 9 inches in length, well and truly squared and dressed. They are laid on a sand cushion one inch thick spread over the foundation and are placed lengthwise across the street, working from the channel drains towards the centre of the road and finishing with a tight fitting crown stone at the centre. The stones should break joint with those of adjacent rows. The joints should be filled with cement or coaltar cement or, preferably, asphaltic cement. At intersections with cross-roads the setts may be laid diagonally.

372. Wood blocks are laid in many shapes and patterns and sizes, but the best experience of wood paving shows that it should consist of plain rectangular blocks, about 3 inches wide, 6 inches deep, 9 inches long, laid with the fibre in a vertical position. The blocks are set end to end in each course as close together as possible. They are sometimes laid on a bed of sand 1 inch thick, spread over a good foundation of concrete, and sometimes mastic asphalt half inch thick, or one inch of cement and sand take the place of the layer of sand, which again is sometimes omitted, the blocks being laid directly on the foundation. An expansion joint is provided near the kerb. This may be a longitudinal joint 1½ inch wide, filled up with sand or pitch. The joints between blocks are filled with cement or pitch, the latter being the better of the two.

373. There are two kinds of wood pavement, *viz.*, those made with soft woods and those made with hard woods. For the former, Baltic deal is generally used, and for the latter, jarrah and karri from Australia. It is usual to impregnate all soft wood paving blocks with a preservative, generally creosote; and this practice has of late been extended to hard wood blocks.

374. Bricks are seldom used in England for paving carriageways, but sometimes find a place in a sidewalk. In America, however, the

roadway is frequently paved with bricks of a superior quality very carefully tested and laid on a concrete foundation covered with a 1½-inch layer of sand or asphalt, the joints being filled with asphalt. In India brick pavements are sometimes laid in narrow streets in connection with drainage schemes, the drainage gutter being along the centre of the road and the bricks being laid on a kankar or concrete foundation and set in lime mortar.

375. There are many varieties of stone or asphalt pavements. One of the former is the Durax pavement, which consists of small stone blocks, about 2½ inches each way, shaped to fit into a series of oyster shell patterns on the road. It is also known as Kleinpflatter. Another is the Belgian block pavement formed of stones in the shape of truncated pyramids having bases 5 to 6 inches square and depths of from 7 to 8 inches. As it was impossible to maintain a smooth surface with these irregular shaped blocks, the rectangular block pavement was ultimately adopted, but the Belgian block will sometimes be found mentioned in road literature.

376. Of mixtures for asphalt pavements Pitchmac needs to be mentioned. References to several others, Camarco, Fluxphalte, Mexphalte, are to be found in a report on the third International Congress, 1913, by Mr. R. J. Kent, A.M.I.C.E., Superintending Engineer, Bombay Public Works Department, who was the delegate of the Government of India to the Congress, and Lithomac, Cormastic, Roadamant, Plascom and Roadoleum are other names that have been adopted for proprietary materials. Rocmac is another. It is a composition of silicate of soda, sugar, and other ingredients, and a specially selected limestone which contains a large proportion of carbonate of lime.

377. Pitchmac is the name given to a standard mixture of pitch prepared by Mr. Brodie, the City Engineer of Liverpool, and used in a double grouting process. On a 10-inch hand pitched foundation laid and consolidated, a layer of dry macadam of 2½-inch gauge stone is spread evenly to a depth of about 3½ inches; this layer after being rolled with a light steam-roller is grouted with a hot mixture of pitch and creosote oil (prepared in accordance with a very special specification) and again rolled while hot till the mass is thoroughly consolidated. A second layer of macadam of 1½-inch gauge stones, 3 inches deep, is then laid, preferably while the lower layer is still hot. After being rolled dry, it is similarly grouted and again rolled till consolidated. The surface is then finished off with a sprinkling of dry chippings. The pitch mixture is of a very special kind based on information gained by the analysis of a specimen

of old pitch that was found to be as good as new after many years' wear.

378. An ideal pavement should be durable, noiseless, easily cleaned, and easily made dustless, not slippery for traffic under varying climatic conditions, easily maintained, have a low tractive resistance, low first cost, low maintenance cost, a long life, an impervious surface that will not produce dust or mud, and a good appearance ; but it is not possible to say which pavement is the best when all these factors are taken into consideration, for prices and other conditions vary. The table given in the following paragraph will give an idea of the relative values which may be assigned in ordinary circumstances to various pavements.

379. Mr. Boulnois in "The Construction of Carriageways and Footways" writes :—

"From a close study of the theoretical and practical essentials of a good paving material the author has ventured to prepare the following table, which he thinks may serve as some guide to those who are investigating the question as to what is the best pavement to use, always bearing in mind that everyone must be greatly influenced by his own special requirements of local conditions and surroundings." :—

TABLE VII.

Description of meterial.	Ease of traction.	Foothold.	Cleanliness.	Noiselessness.	Durability.	Economy.	Facility of repairs.	Suitability to all classes of traffic.	Suitability to all grades.	Uniformly of wear.	Impermeability.	Appearance.
Asphalt. ...	1	4	1	2	2	2	1	2	4	2	1	1
Bricks, ...	2	1	3	3	3	3	3	3	1	4	3	3
Granite, ...	4	3	2	4	1	1	2	4	2	1	2	4
Wood, ...	3	2	4	1	4	4	4	1	3	3	4	2

The numbers refer to order of merit.

This table, while everyone may not accept it as correct, gives a comprehensive idea of the advantages and disadvantages of the pavements mentioned, and it is not necessary to consider these in detail, more especially as they have not all been thoroughly tested in India. Wood blocks have not been a success ; asphalt is found to soften in very hot weather, and Indian bricks are not hard enough to stand heavy traffic.

Granite setts have been used with some success in Cawnpore, and it is probable that this form of pavement will be more used in places where there is concentrated heavy traffic and noise is not objected to, but for some time to come the majority of roads in India must be of kunkar or stone, water bound, with surfaces tar painted where this is practicable.

380. As a rule, gutters in city streets in the United Provinces are not included in road ~~projects~~, but are built as adjuncts to sanitary works in connection with sewers, but cases may arise in which they may form part of a road estimate.

381. The simplest and most effective gutter is the form known as the kerb and channel where the bed of the gutter continues the road slope and the kerb forms the edge of the sidewalk. Many kinds of material may form the kerb and channel and the details of their shape and design may vary, but the simplest form is one in which the road material forms the channel and rests up against a vertical slab, or block of stone, or concrete, which defines the edge of the sidewalk, except when the sidewalk is laid some distance from the kerb. Often the roadway material is re-placed by stone or concrete slabs which form the bed of the channel. This is the case with asphalt, which rots when water lies on it and broken stone which is not good material for a channel.

382. The kerb and gutter should not form too high a step for pedestrians, nor should it be very shallow, or the gutter will overflow, or carriages run on to the sidewalk. In streets that have a good longitudinal slope, the gutter can have a uniform depth, the water being drawn off by means of inlets at suitable intervals, but where the road is nearly level, the gutter must increase in depth as the inlet is approached. This can be done with a stone kerb and gutter, but not with a concrete kerb and gutter which is made in a ~~mould~~. Except in extreme cases, the gutter should not be deeper than 9 inches, nor shallower than 3 inches ; and, ordinarily, it should not be more than 8 nor less than 4 inches, usually it is 5 or 6 inches, and in cases where one side of the street is higher than the other, it may be necessary to put in a double kerb stepping from the sidewalk to the carriageway.

383. Sidewalks may be of any suitable width. In the majority of cases 5 feet will be enough, but this may be increased if a spacious sidewalk is wanted where there is much pedestrian traffic, as in front of retail shops. They may be of concrete, or brick, or stone, or tar macadam laid on a suitable foundation of concrete, the depth of which will depend on the nature of the soil on which the foundation is laid.

384. Gutter inlets or gullies may be of many patterns. They are

intended to carry off the water from the gutter to the sewer, or to an outfall drain, and their design will depend on the requirements of the sewage scheme. In many cases they consist of a grated metal casting, which can be lifted, and through the gratings of which water flows into a manhole below, from which it is led away through a pipe fixed higher than the bed of the manhole. The manhole can be cleared out from time to time. The pipe leading to the sewer should be trapped. A separate overflow should be provided for storm water when this can be led away to outfall drains independent of the sewer.

CHAPTER XIV.

DIAMETER AND WIDTH OF WHEELS.

385. The Heavy Motor Car Order (1904), in England, fixed the limit of weight of a loaded heavy motor vehicle at 12 tons, with not more than 8 tons on one axle, and the speed was fixed at 8 mile on hour which was reduced to 5 miles an hour for a vehicle without pneumatic or elastic tyres, if its weight, unladen, exceeded 3 tons, or if the registered axle weight on any axle exceeded 6 tons, or if the vehicle drew a trailer. If the vehicle were fitted with pneumatic, or other elastic tyres, the speed allowed was 12 miles an hour if the registered axle weight was below, and 8 miles an hour if it was above, 6 tons. The width of the tyre, if not of rubber, was made to depend on the diameter of the wheel and the axle load, the minimum width for a heavy motor vehicle being fixed at 5 inches and for a trailer at 3 inches, the principle followed being that a load of $7\frac{1}{2}$ cwts. per inch-width was allowed for a wheel 36 inches in diameter, and this could be increased in the proportion of 112 lbs. per inch-width for every 12 inches additional diameter, and had to be reduced in the proportion of 112 lbs. per inch-width for every 6 inches of reduced diameter. The accompanying table shows the resulting widths of wheels required by the rules given above :—

TABLE VIII.

Diameter of wheel in feet.	Unit of registered axle weight per inch-width in cwt.	Maximum weight allowed per axle in tons.	Width of wheel in half inches column 3 ÷ column 2.	Width of wheel in inches.
1	2	3	4	5
2′0″	5·5	8	29·1	15
2′6″	6·5	8	24·6	$12\frac{1}{2}$
3′0″	7·5	8	21·3	11
4′0″	8·5	8	18·8	$9\frac{1}{2}$
5′0″	9·5	8	16·8	$8\frac{1}{2}$

The maximum weight of a heavy motor vehicle, (*i.e.*, one weighing over 2 tons) was fixed at 5 tons (unladen) and of a vehicle and trailer at $6\frac{1}{2}$ tons (unladen), and the maximum axle weight of a trailer was fixed at 4 tons.

386. It is impossible for the whole width of a wide wheel to press equally on the road surface, and it follows that the maximum weight allowed per axle, when wheels of small diameter are used, will damage the road in spite of the reduced unit of registered axle weight allowed, more than when wheels of larger diameter are used. A wheel 14 inches wide would, if it is at right angles to the axle and the axle is horizontal, cut into the road at one edge and, perhaps, not touch it at the other edge. Taking the cross-slope of the road as 1 in 36, it would, theoretically be $\frac{7}{18}$ths of an inch off it. Practically only a part of the width would be carrying the load. When the vehicle was not on the centre of the road, but on one side or the other, the width of the wheel would be doing better work, but there would be some wear due to the tendency of the vehicle to work towards the gutter. The axle would not in this case be horizontal and thh vehicle would be on the tilt. All this points to the necessity for making roads of as good materials as possible, so that as flat a cross-slope as possible, consistent with surface drainage, may be used.

387. It is interesting at this stage to consider the general results of experiments made by M. Morin in 1837 to 1842 upon the resistance to the traction of vehicles. These are, among others, roughly as follows :—

The resistance to rolling of vehicles on solid metalled roads is proportional to the weight, and inversely proportional to the diameter of the wheel, and is very nearly independent of the width of the tyre when it exceeds 3 to 4 inches, but on compressible surfaces, it decreases in proportion to the width of the tyre. It increases to some extent with the velocity on hard roads, but is independent of this on soft surfaces. Springs diminish resistance at high speeds, but not at slow speeds. The destruction of the road is, in all cases, greater as the diameters of the wheels are less, and it is greater in carriages without than with springs.

388. These conclusions were accepted by the scientific world, but were challenged by a civil engineer, M. Dupuit, who, after a series of experiments, came to the conclusion that resistance to traction is directly proportional to the load, independent of the width of the tyre, independent of the velocity, and inversely as the square root of the diameter of the wheel. He allowed that on paved roads which give rise to constant concussion, the resistance increases with the speed, whilst it is diminished by an enlargement of the tyre up to a certain limit.

389. Other experiments have been made from time to time. In 1896, M. Michelin made a series of tests which tend to show that pneumatic tyres give 50 per cent. better results than iron tyres, that solid tyres are inferior to pneumatic tyres and that solid rubber tyres

are better than iron in some cases, especially if the road is sticky, very irregular, or covered with snow, but become inferior to iron tyres if the surface is hard and smooth. His experiments showed that the average proportionate forces exerted in drawing a weight on a good regular macadam road were :—

	Walking.	Trotting.	Quick trotting.
For pneumatics, ...	130	135	135
For iron wheels, ...	138	170	221

At the trot ($6\frac{1}{2}$ miles an hour) and at the quick trot ($9\frac{1}{2}$ miles an hour) the results for pneumatics are the same, from which it may be concluded that, whatever the speed may be within reasonable limits, the force absorbed by traction varies but little upon good ground with pneumatic tyres. Later results show that there is a slight increase with the speed (*see* references to experiments by the British Association Committee in paragraphs 390, 391).

390. In 1902, Mr. Ira O. Baker, M. AM. SOC. C. E., investigated the subject of rolling resistance. The results have been adopted in Chapter II. in which, however, it has not been possible to mention any but general conclusions. Some details will be found in the report of the British Association Committee (of which Sir Alexander Binnie was chairman) appointed to investigate the resistance of road vehicles to traction. A copy of the report, together with a description of the special dynamometer made for the British Association Committee to carry out the researches, is included as an appendix in the 1907 edition of Aitken's "Road Making and Maintenance." The results of the test made by the Committee on pneumatic tyres, on macadam, are here tabulated in approximate figures of pounds per ton :—

TABLE IX.

Pneumatic tyres on macadam.	Speed in miles per hour.								
	8	10	12	14	16	18	20	22	24
A 34″ × $3\frac{1}{2}$″, ..	..	..	..	75	78	81	83	85	87
B 34″ × $4\frac{1}{2}$″, ..	..	..	..	90	93	96	98	101	103
C $2\frac{1}{2}$″, ..	130	134	138	141	144	146	..	..	..

It is curious that the $4\frac{1}{2}$-inch tyre should offer a greater resistance than the $3\frac{1}{2}$-inch tyre. This, the Committee remark, may be due to the fact that the larger tyre was very much thicker than the smaller, rendering it, in consequence, more after the nature of a solid tyre, it being well understood that a perfect pneumatic tyre should have as little inelastic, or comparatively inelastic material about it as possible, or the

greater tractive effort may have been due to the greater cross-section. Repeated experiments alone, the Committee say, can definitely settle this question.

391. Assuming that General Morin's theory is correct, *viz.*, that the draught is inversely proportional to the diameter of the wheel, the results in the case of the 24-inch wheel considered as a 34-inch wheel would be 99 lbs., 102 lbs., 103 lbs. for speeds of 14, 16, 18 miles an hour which approximate to the results in the case of B, but no deduction can be made from this, as the width of the tyre is not the same and the macadam on which the 24-inch wheel was run was older than that on which the tests A and B were made.

[The Second International Road Congress took the draught as inversely proportional to the square root of the wheel diameter].

392. Experiments made by Sir J. Macneil early in the 19th century showed that the resistance to traction of a stage-coach on a metalled road may be represented by :—

$$R = 30 + 4V + \sqrt{10V}.$$

Where V = the velocity in miles per hour and R = the resistance in pounds per ton, this gives the following results :—

When V =	$2\frac{1}{2}$ miles an hour	R = 45 lbs. per ton.
V =	4 ,, ,,	R = 52 ,, ,,
V =	6 ,, ,,	R = 62 ,, ,,
V =	8 ,, ,,	R = 71 ,, ,,
V =	10 ,, ,,	R = 80 ,, ,,

These show approximately the increase in resistance to traction with iron tyres on a metalled road caused by an increase in the speed.

393. Comparing the results obtained by this formula with the results obtained by the British Association Committee, in the case of 34 × $4\frac{1}{2}$ inch pneumatic tyres, it will be seen from the following table that the resistance to traction is greater in the case of the stage-coach, even on the assumption that it had 34-inch wheels. It probably had larger wheels, and if this was so, the comparison would be still more in favour of the pneumatic tyre.

TABLE X.

Speed in miles per hour, ..	8	10	12	14	16	18	20	
Stage-coach, ...	71	80	89	98	107	116	124	lbs. per ton.
Pneumatic 34" × $3\frac{1}{2}$", ..	..	..	..	75	78	81	83	Ditto.

394. Some of the rules of the English Heavy Motor Car Order (1904) were given at the beginning of this chapter, and it was stated that the

unit of weight per inch-width of tyre in the case of a wheel 3 feet in diameter was fixed at 7½ cwts., *i.e.*, 840 lbs. with a proportionate increase of 112 lbs. for each addition of 12 inches to the diameter. This intensity of pressure is considered too great. In the case of a wheel of 5½ feet diameter, a weight of 10 cwts. is allowed per inch-width of wheel, which is nearly twice as much as that of a 15-ton roller having about the same diameter of wheel, and the matter was discussed at the First International Road Congress at Paris in 1908, the English delegates expressing the opinion that, after four years' experience of the working of the Heavy Motor Car Order, they thought the weight allowed was excessive for macadam roads. The delegates resolved to recommend the Congress to reduce the unit to 600 lbs. retaining the proportionate increase, but no change was made.

395. An extract from the rules framed for the United Provinces under the Indian Motor Vehicles Act, 1914, will be found in Appendix 4.

396. When it is considered that the maximum weight allowed on one axle, in England, is 8 tons and the total weight 12 tons, it is surprising to find that these Motor Vehicles Rules allow 11 tons on one axle and a total weight of 16 tons. The intention evidently is to include steam road rollers in the rules. Under these rules a wheel 2 feet in diameter carrying half the axle weight of 11 tons would need to be 20 inches wide, and when the axle was horizontal, the variation of pressure between the inner and the outer edge of the wheel on a road that was not flat in cross-section would be very great, if, indeed, the outer edge of the wheel touched the road. Large wheels and light axle loads should, therefore, be insisted on, and there should be special rules for road rollers.

397. The speed allowed in India agrees with that allowed in England with the substitution of 7 miles per hour for 8 miles, and a heavy motor vehicle is defined as one weighing over 3 tons unladen if fitted with pneumatic tyres, and 2 tons unladen if not so fitted.

398. The unit of registered axle weight in the United Provinces, *viz.*, 7½ cwts. is the same for wheels of 3 feet diameter as in the English order of 1904. For wheels greater or less in diameter than 3 feet, the English and the United Provinces rules agree as to the unit of axle weight, but, as mentioned above, the total weight allowed on an axle is more in India than in England, though the roads are not so well able to stand heavy traffic. It has been found in America that 7-ton trucks are too heavy and even 5-ton trucks carrying 6 tons damage macadam roads too much. Lighter trucks are advised for Indian roads.

399. Under the English "Highways and Locomotives Amendment Act, 1878," a county authority may make regulations for tyre widths of vehicles, drawn by animal power, in proportion to the loads carried. The

tyre widths prescribed in different counties for the same loads under this Act vary considerably, the average load allowed on each wheel being, for 4-wheeled vehicles :—

For tyres	3	inches wide,	16·8	cwts., or	5·6	cwts. per inch-width.
Do.	4	do.	19·6	do.,	4·9	ditto.
Do.	6	do.	25·2	do.,	4·2	ditto.
Do.	9	do.	27·8	do.,	3·1	ditto.

and for 2-wheeled vehicles :—

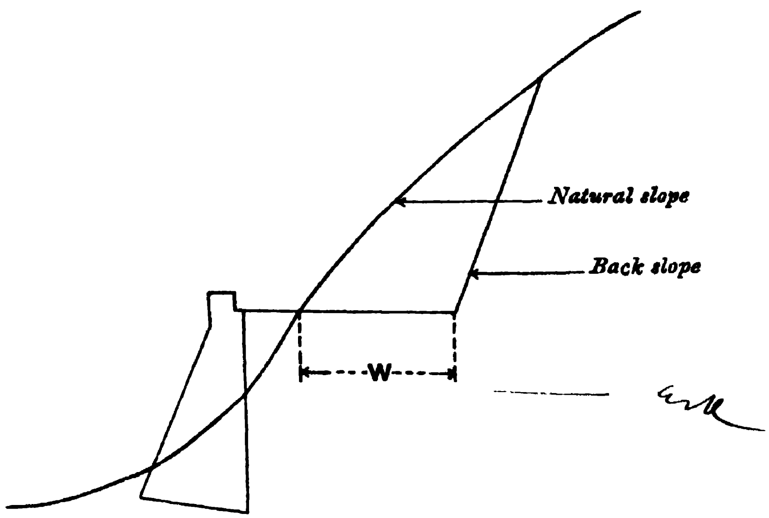
For tyres	3	inches wide,	14·8	cwts., or	4·9	cwts. per inch-width.
Do.	4	do.	24·1	do.,	6·0	ditto.
Do.	7	do.	28·2	do.,	4·7	ditto.
Do	9	do.	28·0	do.,	3·1	ditto

In each case, the weight per inch-width is less than is allowed for wheels 3 feet in diameter under the Heavy Motor Car Order, 1904, which allows $7\frac{1}{2}$ cwts. per inch-width, and the average is about one half of what is allowed in the case of a wheel 5 feet in diameter.

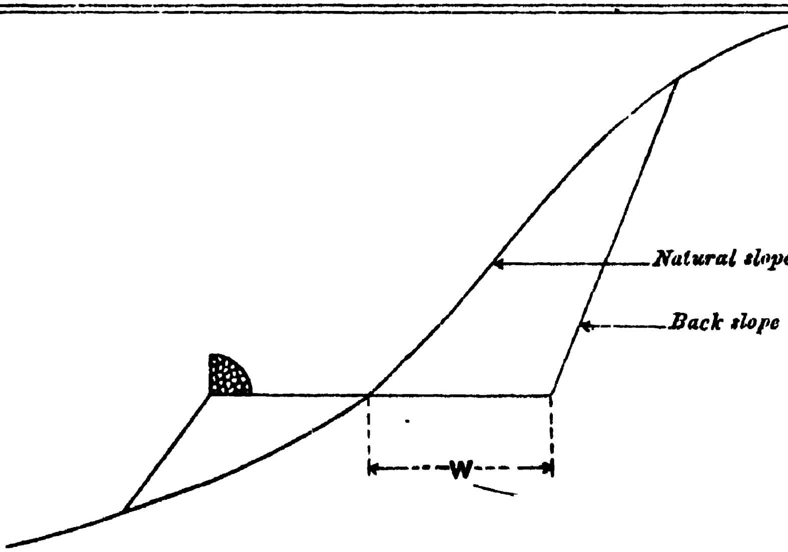
400. In India, cart wheels are very badly designed, and it would be advisable, seeing that most roads are of kankar, to limit the loads that carts carry to 6 maunds per inch-width of wheel 4 feet in diameter ; increasing the load and decreasing it in proportion to the diameter. Carts with two wheels with $1\frac{1}{2}$-inch tyres should, therefore, in a kankar district carry $2 \times 1\frac{1}{2} \times 6$ maunds $= 18$ maunds (including the weight of the cart), and if they are to carry more, the tyre widths should be increased. With 3-inch tyres the gross load should be 36 maunds and with 4-inch tyres 48 maunds. License fees might be charged at a figure in rupees obtained by dividing 144 or other suitable number by the product of the wheel diameter in feet and the tyre width in inches.

401. Cases are not unknown of carts carrying 70 or 80 maunds on two $1\frac{1}{4}$-inch tyres fitted on badly-shaped wheels, which wobble as they roll, and themselves made of a semi-circular section instead of being flat. With such tyres and wheels and loads, roads of kankar and of stone are soon damaged. Wheels should be circular in shape, and it is suggested that they should not deviate more than 3 degrees from the vertical and all tyres should be smooth and flat. The ribbed tyres allowed in Upper India, under the Motor Vehicles Rules, are a mistake, and should be abolished by law, and rules regulating the shape and dimensions of cart wheels, the widths of tyres, the loads that may be carried need to be introduced in the interests of the community generally.

402. In Appendix 5 will be found the resolutions of the International Road Congresses held in Paris, Brussels and London which touch on various points in modern practice and are of interest to road engineers in all countries.



Sectional areas of cutting on hill sides
in square feet.
Retaining Walls.
Breast Walls.



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APPENDIX 1.

Sectional areas of cutting on hill sides in square feet.

Retaining walls.

Breast walls.

Sectional areas of cuttings on

Natural slope.	Back slope.	Width of cut.										
		5	6	7	8	9	10	11	12	13	14	15
5°	45°	1	2	2	3	4	5	6	7	8	10	11
...	60	1	2	2	3	4	4	6	7	8	9	10
...	75	1	1	2	3	4	4	5	6	8	9	10
...	80	1	1	2	3	3	4	5	6	7	9	10
...	90	1	1	2	3	3	4	5	6	7	9	10
10°	40°	3	4	5	7	9	11	14	16	19	22	25
...	60	2	3	5	6	8	10	12	14	17	19	22
...	75	2	3	4	6	7	9	11	13	16	18	21
...	80	2	3	4	6	7	9	11	13	15	18	21
...	90	2	3	4	6	7	9	11	13	15	17	2
15°	40°	5	6	10	12	16	20	24	28	33	39	24
...	60	4	6	8	10	13	16	19	23	27	31	36
...	75	3	5	7	9	12	14	17	21	24	28	32
...	80	3	5	7	9	11	14	17	20	24	28	34
...	90	3	5	6	8	11	13	16	19	23	26	30
20°	40°	8	11	16	20	26	32	39	46	51	63	72
...	60	6	8	11	15	19	23	28	33	99	45	52
...	75	5	7	10	13	16	20	24	29	34	39	45
...	80	5	7	9	12	16	19	24	28	33	38	44
...	85	5	7	9	12	15	19	23	27	32	37	42
...	90	4	6	9	12	15	18	22	26	31	36	41
25°	40°	13	19	26	34	43	52	63	76	89	103	11
...	60	8	1	16	20	26	32	39	46	54	63	72
...	75	7	10	13	1	21	27	32	38	45	52	60
...	80	6	9	12	16	20	25	31	37	43	50	57
...	85	6	9	12	15	20	24	29	35	41	48	50
...	90	6	8	11	15	19	23	28	34	39	46	52

hill sides in square feet.

ting in feet.											
16	17	18	19	20	21	22	23	24	25	Back slope.	Natural slope.
12	14	16	18	20	22	24	26	28	30	40°	5°
12	13	15	17	18	20	22	24	26	28	60	...
11	13	15	16	18	20	22	24	26	28	75	...
11	13	14	16	18	20	21	23	25	28	80	...
11	13	14	16	17	19	21	23	25	27	90	...
29	32	36	40	45	49	54	59	64	70	40°	10°
25	28	32	36	39	43	48	52	56	62	60	...
24	27	30	33	37	41	45	49	53	53	75	...
23	26	29	33	36	40	44	48	52	57	80	...
23	25	29	32	35	39	43	47	51	55	90	...
50	57	64	71	79	87	95	104	113	123	40°	15°
42	46	52	57	64	70	77	84	92	98	60	...
37	42	47	52	58	64	70	76	83	90	75	...
36	41	46	51	56	62	68	76	81	88	80	...
34	39	43	48	54	59	65	71	77	84	90	...
82	93	104	116	128	142	155	170	185	201	40°	20°
59	67	75	83	92	101	112	122	133	144	60	...
51	58	65	73	80	89	97	106	116	126	75	...
50	56	63	70	78	86	94	103	111	121	80	...
48	54	61	68	75	82	91	99	108	117	85	...
46	52	59	65	72	80	88	96	104	113	90	...
185	162	170	189	210	231	254	278	302	328	40°	25°
82	92	103	115	127	141	154	169	184	199	60	..
68	77	86	96	116	117	129	141	152	166	75	...
65	73	82	92	102	112	123	134	146	159	80	...
62	70	79	88	97	107	118	129	140	152	85	...
60	67	75	84	93	103	113	123	134	146	90	...

Sectional areas of cuttings on

Natural slope.	Back slope.	Width of cut.										
		5	6	7	8	9	10	11	12	13	14	15
30°	35°	41	59	80	105	133	104	199	237	278	322	369
...	40	23	33	45	59	75	92	112	133	156	181	208
...	45	17	24	33	44	55	68	83	98	115	134	153
...	50	14	20	27	36	45	56	68	81	95	110	126
...	55	12	17	24	31	39	48	58	70	81	95	109
...	60	11	15	21	28	35	53	52	62	73	85	97
...	65	10	14	19	25	32	39	48	57	66	77	89
...	70	9	13	18	23	29	36	44	53	62	71	82
...	75	8	12	17	22	27	34	41	49	57	67	77
...	80	8	11	16	20	26	32	39	46	54	63	72
...	85	8	11	15	19	24	30	37	43	51	60	68
...	90	7	10	14	18	23	29	35	41	49	56	56
35°	40°	53	76	103	135	171	212	256	305	358	414	477
...	45	29	42	57	74	94	117	141	168	197	229	263
...	50	21	30	41	54	69	85	103	122	143	166	191
...	55	17	25	34	44	55	69	83	99	116	135	154
...	60	15	21	29	37	47	59	71	85	99	115	132
...	65	13	19	25	33	42	52	63	75	88	102	117
...	70	12	17	23	30	38	47	57	68	79	92	106
...	75	11	15	21	27	35	43	52	62	72	84	79
...	80	10	14	19	25	32	40	48	57	67	78	90
...	85	9	13	18	24	30	37	45	54	62	73	84
...	90	9	12	17	22	28	35	42	51	59	69	79
40°	45°	65	94	128	167	211	261	316	376	441	512	588
.	50	35	51	69	91	115	142	171	204	189	277	318
...	55	25	36	50	65	82	102	123	146	172	199	29
...	60	20	29	40	52	66	81	98	117	137	199	183
..	65	17	25	34	44	56	69	83	99	116	135	155
...	70	15	22	29	39	49	60	73	87	102	[illegible]	136
...	75	13	19	26	35	44	54	65	78	91	106	122
...	80	12	18	24	31	40	49	59	71	83	96	111
...	85	11	16	22	29	45	45	65	65	76	89	102
...	90	10	15	20	27	34	42	51	60	71	82	94

hill sides in square feet.

ting in feet.											
16	17	18	19	20	21	22	23	24	25	Back slope.	Natural slope.
420	274	531	592	656	723	794	868	945	1,024	35°	30
286	267	299	333	370	406	447	488	497	577	40	..
175	197	221	246	273	301	329	361	398	426	45	..
143	162	181	202	224	246	271	296	322	349	50	..
124	140	157	175	194	213	234	256	279	302	55	..
111	125	140	156	173	191	210	229	249	271	60	..
101	114	128	142	158	174	191	208	327	246	65	..
93	105	118	132	146	160	176	193	210	227	70	..
87	99	110	123	136	150	165	180	196	213	75	..
82	93	104	116	129	142	155	170	185	201	80	..
77	87	98	110	121	134	147	161	175	190	85	..
74	83	93	104	115	127	139	152	106	180	90	..
543	618	687	766	848	935	1,026	1,122	1,222	1,326	40°	35°
298	337	378	421	466	514	564	617	672	729	45	..
217	245	275	306	339	374	410	448	488	530	50	..
176	198	222	248	275	308	331	363	396	429	55	..
150	170	190	212	235	259	284	310	338	367	60	..
133	150	168	188	208	229	252	275	299	325	65	..
120	136	152	170	188	207	227	249	271	294	70	..
110	124	139	155	172	190	209	228	248	269	75	..
102	115	129	145	160	176	193	211	230	249	80	..
96	108	121	135	150	165	181	198	216	234	85	..
90	101	113	126	140	154	169	185	202	219	90	..
669	755	846	943	1,045	1,152	1,264	1,382	1,504	1,632	45°	40°
362	409	458	511	566	624	685	748	813	884	50	..
260	294	330	367	406	448	492	537	585	635	55	..
208	235	264	294	326	359	394	431	469	509	60	..
176	199	228	249	275	303	333	364	396	430	65	..
155	174	196	218	242	266	292	319	348	377	70	..
139	156	175	195	216	238	262	286	312	338	75	..
126	142	159	178	197	217	238	260	283	307	80	..
116	131	147	163	181	200	219	240	261	283	85	..
107	121	136	151	168	185	203	222	241	262	90	..

Sectional areas of cuttings on

Natural slope.	Back slope.	Width of cut-										
		5	6	7	8	9	10	11	12	13	14	15
45°	50°	78	112	152	199	252	311	276	248	525	610	727
..	55	42	60	82	107	135	166	202	239	281	226	400
..	60	39	42	58	76	96	118	143	170	200	231	266
..	65	23	34	46	60	76	94	113	135	158	186	210
..	70	19	28	38	50	64	78	95	113	132	154	176
..	75	17	24	35	44	55	68	82	98	115	134	151
..	80	15	22	30	39	49	61	73	87	103	119	136
..	85	13	19	26	34	44	55	66	78	92	106	123
..	90	12	18	24	32	40	50	60	72	32	98	112
50°	55°	90	130	179	231	292	360	436	519	609	706	811
..	60	48	69	93	122	154	191	231	274	322	374	429
..	65	33	48	66	86	108	134	162	193	226	262	302
..	70	26	38	51	67	85	105	127	152	178	206	237
..	75	22	31	43	56	71	87	106	126	148	172	197
..	80	19	27	36	48	61	75	91	108	127	148	170
..	85	17	24	32	42	54	66	80	96	112	130	150
..	90	14	21	29	38	48	59	72	86	101	117	134
55	60°	102	146	99	261	330	407	492	586	688	798	916
..	65	53	77	105	137	173	214	259	308	361	414	481
..	70	37	53	73	95	120	149	180	214	251	291	335
..	75	29	41	57	74	94	116	140	169	195	227	260
..	80	24	34	47	61	77	95	115	137	161	187	215
..	85	20	29	40	52	66	82	99	117	130	160	184
..	90	18	26	35	46	58	71	86	103	121	140	161
60°	65°	112	162	221	288	365	450	545	648	761	883	1,013
..	70	58	84	115	150	190	284	288	337	396	459	527
..	75	40	58	79	103	131	161	196	233	278	317	364
..	80	31	45	61	80	101	125	151	180	211	244	280
..	85	25	37	50	65	88	102	124	147	178	201	230
..	90	22	31	42	55	70	86	105	125	146	170	195

hill sides in square feet.

ting in feet.											
16	17	18	19	20	21	22	23	24	25	Back slope.	Natural slope.
797	899	1,008	1,123	1,245	1,373	1,507	1,449	1,793	1,946	50	45°
426	481	540	601	666	734	805	880	958	1,040	55	..
302	341	382	427	473	521	572	625	681	739	60	..
240	271	303	338	375	413	453	495	539	585	65	..
201	227	254	283	314	346	380	415	452	491	70	..
175	197	221	246	273	301	329	361	393	427	75	..
155	175	197	219	243	268	294	321	350	379	80	..
140	158	177	197	218	241	265	289	315	342	85	..
128	144	162	180	200	220	242	264	288	312	90	..
923	1,041	1,167	1,301	1,442	1,590	1,745	1,907	2,094	2,153	55°	50°
488	551	618	688	762	840	922	1,008	1,098	1,191	60	..
343	387	434	484	536	590	648	708	77	837	65	..
269	304	341	380	421	461	509	556	606	657	70	..
224	253	284	316	350	385	423	462	503	536	75	..
193	218	244	272	302	332	365	399	434	471	80	..
170	192	215	240	266	293	321	351	382	415	85	..
152	173	193	215	238	262	288	315	343	372	90	..
1,042	1,176	1,319	1,469	1,628	1,795	1,970	2,154	2,345	2,544	60°	55°
547	618	693	772	853	941	1,032	1,128	1,229	1,333	65	..
381	430	482	537	595	655	719	786	856	929	70	..
296	334	375	418	463	510	559	612	666	722	75	..
244	276	309	344	382	420	461	504	549	596	80	..
209	236	264	295	326	360	395	432	470	510	85	..
183	206	231	258	286	314	345	377	411	446	90	..
1,153	1,301	1,459	1,626	1,804	1,988	2,182	2,385	2,597	2,818	65°	60°
600	677	759	846	936	1,032	1,183	1,288	1,348	1,462	70	..
414	467	524	583	646	712	781	854	930	1,009	75	..
319	360	404	450	499	550	603	660	718	779	80	..
262	296	331	368	408	449	493	539	587	637	85	..
222	250	281	313	346	382	449	458	499	541	90	..

Sectional areas of cuttings on

Natural slope	Back slope.	Width of cut-										
		5	6	7	8	9	10	11	12	13	14	15
65°	70°	122	176	293	313	396	489	592	705	826	959	1,101
...	75	63	91	123	161	204	252	304	362	425	498	566
...	80	43	62	84	110	140	172	208	248	291	338	388
...	85	33	47	65	84	107	132	160	190	223	259	297
...	90	27	38	52	68	86	107	130	154	181	210	241
70°	75°	130	188	256	334	422	522	631	751	882	1,023	1,124
...	80	66	96	130	170	215	266	322	383	450	522	599
...	85	45	65	89	116	146	181	219	260	306	354	400
...	90	34	49	67	88	111	137	166	198	232	269	337
75°	80°	137	196	268	350	443	547	661	787	924	1,070	1,229
...	85	69	100	135	177	224	276	333	398	467	542	620
...	90	47	67	91	119	151	187	226	269	315	366	423
80°	85°	141	203	276	361	457	564	682	813	953	1,105	1,620
...	90	71	102	139	181	229	283	342	408	778	555	868
85°	90°	143	206	280	366	463	572	693	824	967	1,122	1,287

hill sides in square feet.

ting in feet.											
16	17	18	19	20	21	22	23	24	25	Back slope.	Natural slope.
1,253	1,414	1,586	1,767	1,958	2,158	2,369	2,589	2,819	3,059	70°	65°
644	727	817	908	1,006	1,109	1,257	1,330	1,448	1,571	75	..
441	498	558	622	690	759	833	911	992	1,076	80	..
338	381	427	476	528	582	638	698	760	824	85	..
274	309	347	386	428	472	518	506	616	669	90	..
1,336	1,508	1,691	1,884	2,087	2,201	2,525	2 760	3,006	3,261	75°	70°
681	769	862	960	1,064	1,178	1,287	1,407	1,532	1,662	80	..
463	522	586	652	723	797	875	956	1,041	1,129	85	..
352	397	445	496	550	563	665	727	791	859	90	..
1,399	1,580	1,771	1,983	2,187	2,411	2,646	2,892	3,169	3,427	80°	75°
708	799	896	998	1,106	1,219	1,338	1,462	1,592	1,727	85	..
477	539	604	673	746	822	908	987	1,074	1,166	90	..
1,448	1,629	1,827	1,035	2,255	2,486	2,729	2,982	3,247	3,523	85°	80°
724	815	917	1,022	1,132	1,248	1,369	1,497	1,630	1,769	90	..
1,465	1,654	1,855	2,066	2,290	2,524	2,770	3,028	3,297	3,577	90°	85°

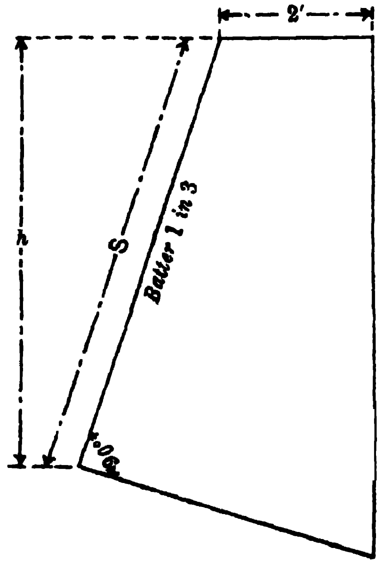
SECTIONAL AREAS OF RETAINING WALLS.

TOP WIDTH 2 FT. BATTER 1 IN 3 WORKED OUT BY

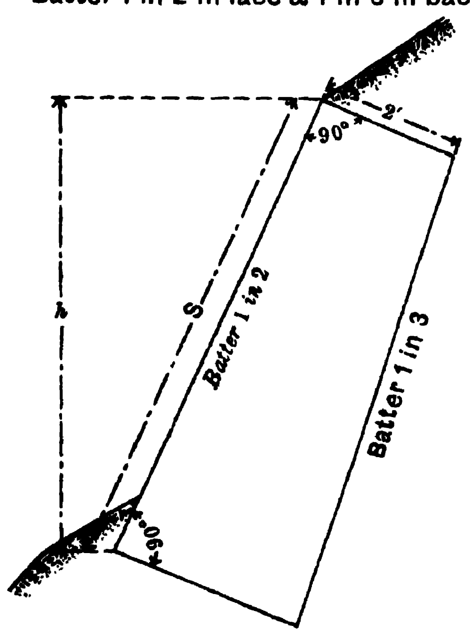
Formula $0{\cdot}185h^2 + 2{\cdot}28h + 0{\cdot}67 = \text{area}$.

Vertical height or h.	Area in sqr. feet.	Vertical height or h.	Area in sqr. feet.	Vertical height or h.	Area in sqr. feet.	Vertical height or h.	Area in sqr. feet.
3	8·99	10	41·37	17	91·87	24	160·51
„ ¼	9·83	„ ¼	42·86	„ ¼	94·01	„ ¼	163·29
„ ½	10·70	„ ½	44·37	„ ½	96·17	„ ½	166·10
„ ¾	14·59	„ ¾	45·91	„ ¾	98·36	„ ¾	168 98
4	12·51	11	47·47	18	100·57	25	171·79
„ ¼	13·44	„ ¼	49·06	„ ¼	102·80	„ ¼	174·67
„ ½	14·40	„ ½	50 66	„ ½	105·05	„ ½	177·57
„ ¾	15·38	„ ¾	52·29	„ ¾	107·33	„ ¾	180·50
5	16·39	12	53·95	19	109·63	26	183·45
„ ¼	17·42	„ ¼	55·62	„ ¼	111·95	„ ¼	186·42
„ ½	18·47	„ ½	57·82	„ ½	114·30	„ ½	189·41
„ ¾	19·58	„ ¾	49·04	„ ¾	116·67	„ ¾	192·43
6	20·65	13	60·79	20	119 07	27	195·47
„ ¼	21·77	„ ¼	62·56	„ ¼	121·48	„ ¼	198·58
„ ½	22·91	„ ½	64·35	„ ½	123·93	„ ½	201·62
„ ¾	24·08	„ ¾	66·17	„ ¾	126·38	„ ¾	204·73
7	25·27	14	68·01	21	128·87	28	207 87
„ ¼	26·48	„ ¼	69 87	„ ¼	131·38	„ ¼	211·02
„ ½	27·72	„ ½	71·75	„ ½	133·91	„ ½	214·20
„ ¾	28·98	„ ¾	73·66	„ ¾	136·47	„ ¾	217·40
8	30·27	15	75·59	22	139·05	29	220·63
„ ¼	31·57	„ ¼	77·55	„ ¼	141·65	„ ¼	223·88
„ ½	32·90	„ ½	79·52	„ ½	144·27	„ ½	227·15
„ ¾	34·25	„ ¾	81·52	„ ¾	146·92	„ ¾	230·45
9	35·63	16	83·55	23	149·59	30	233 77
„ ¼	37·03	„ ¼	85·59	„ ¼	152·28		
„ ½	38·45	„ ½	87·66	„ ½	155·00		
„ ¾	39·90	„ ¾	89·75	„ ¾	157·74		

Section of Retaining Walls
Batter I in 3.



Section of Breast Walls
Batter 1 in 2 in face & 1 in 3 in back.



No. 639-20x1500

SECTIONAL AREAS OF RETAINING WALLS.

Top width 2 ft. batter 1 in 3.

Areas for Front Slope Length S.

Given Slope Length S.	Corresponding Vertical height or h.	Area in sqr. feet	Given Slope Length S.	Corresponding Vertical height or h.	Areas in sqr. feet.	Given Slope Length S.	Corresponding Vertical height or h.	Area in sqr feet.	Given Slope Length S.	Corresponding Vertical height or h.	Area in sqr. feet
3	2·85	8·50	10	9·50	38·45	17	16·15	84·77	24	22·80	147·45
„ ¼	3·09	9·29	„ ¼	9·74	39·84	„ ¼	16·39	86·75	„ ¼	23·04	150·02
„ ½	3·82	10·08	„ ½	9·97	41·19	„ ½	16·62	88·66	„ ½	23·27	152·47
„ ¾	3·56	10·92	„ ¾	10·21	42·62	„ ¾	16·86	90·68	„ ¾	23·51	155·11
4	3·80	11·78	11	10·45	44·07	18	17·10	92·72	25	23·75	157·74
„ ¼	4·04	12·66	„ ¼	10·69	45·54	„ ¼	17·34	94·78	„ ¼	23·99	160·39
„ ½	4·27	13·52	„ ½	10·92	46·97	„ ½	17·57	96·78	„ ½	24·22	162·95
„ ¾	4·51	14·44	„ ¾	11·16	48·48	„ ¾	17·81	98·88	„ ¾	24·46	165·65
5	4·75	15·39	12	11·40	50·02	19	18·05	100·01	26	24·70	168·36
„ ¼	4·99	16·34	„ ¼	11·64	51·57	„ ¼	18·29	103·16	„ ¼	24·94	171·10
„ ½	5·22	17·30	„ ½	11·87	53·08	„ ½	18·52	105·23	„ ½	25·17	173·74
„ ¾	5·46	18·30	„ ¾	12·11	54·68	„ ¾	18·76	107·42	„ ¾	25·41	176·52
6	5·70	19·33	13	12·35	56·30	20	19·00	109·63	27	25·65	179·32
„ ¼	5·94	20·38	„ ¼	12·59	57·94	„ ¼	19·24	111·86	„ ¼	25·89	182·14
„ ½	6·17	21·40	„ ½	12·82	59·35	„ ½	19·47	114·01	„ ½	26·12	184·87
„ ¾	6·41	22·50	„ ¾	13·06	61·24	„ ¾	19·71	116·29	„ ¾	26·36	187·73
7	6·65	23·61	14	13·30	62·92	21	19·95	118·58	28	26·60	190·62
„ ¼	6·89	24·74	„ ¼	13·54	64·64	„ ¼	20·19	120·90	„ ¼	26·84	193·52
„ ½	7·12	25·84	„ ½	13·77	66·31	„ ½	20·42	123·14	„ ½	27·07	196·32
„ ¾	7·36	27·03	„ ¾	14·01	38·08	„ ¾	20·66	125·49	„ ¾	27·31	199·27
8	7·60	28·22	15	14·25	69·87	22	20·90	127·87	29	27·55	202·06
„ ¼	7·84	29·44	„ ¼	14·49	71·68	„ ¼	21·14	130·28	„ ¼	27·79	205·11
„ ½	8·07	30·63	„ ½	14·72	73·38	„ ½	21·37	132·59	„ ½	28·02	208·23
„ ¾	8·31	31·89	„ ¾	14·96	75·28	„ ¾	21·61	135·03	„ ¾	28·26	211·1
9	8·55	33·17	16	15·20	77·15	23	21·85	137·49	30	28·50	214·20
„ ¼	8·79	34·47	„ ¼	15·44	79·04	„ ¼	22·09	139·97			
„ ½	9·02	35·74	„ ½	15·67	80·88	„ ½	22·32	142·38			
„ ¾	9·26	37·09	„ ¾	15·91	82·81	„ ¾	22·56	144·99			

SECTIONAL AREAS OF BREAST WALLS.

FOR SLOPE S.

Top width 2 feet, Front Slope 1 in 2, Back Slope 1 in 3.

Area = ½ sum of two parallel sides × S.

Front Slope S.	Area in square feet.	Front Slope S.	Area in square feet.	Front Slope S.	Area in square feet.	Front Slope S.	Area in square feet.
3	6·65	10	27·29	17	55·06	24	89·99
„ ¼	7·27	„ ¼	28·14	„ ¼	56·19	„ ¼	91·36
„ ½	7·89	„ ½	29·02	„ ½	57·32	„ ½	92·75
„ ¾	8·52	„ ¾	29·90	„ ¾	58·46	„ ¾	94·15
4	9·16	11	30·82	18	59·61	25	95·66
„ ¼	9·81	„ ¼	51·72	„ ¼	60·77	„ ¼	96·97
„ ½	10·47	„ ½	32·64	„ ½	61·94	„ ½	98·40
„ ¾	11·14	„ ¾	33·56	„ ¾	63·12	„ ¾	99·83
5	11·82	12	34·49	19	64·31	26	101·28
„ ¼	12·50	„ ¼	35·43	„ ¼	65·51	„ ¼	102·73
„ ½	13·20	„ ½	36·39	„ ½	66·71	„ ½	104·19
„ ¾	13·80	„ ¾	37·34	„ ¾	67·93	„ ¾	105·66
6	14·62	13	88·32	20	69·16	27	107·14
„ ¼	15·34	„ ¼	89·29	„ ¼	70·39	„ ¼	108·63
„ ½	16·07	„ ½	40·28	„ ½	71·63	„ ½	110·12
„ ¾	16·82	„ ¾	41·28	„ ¾	72·88	„ ¾	111·63
7	17·57	14	42·28	21	74·14	28	113·15
„ ¼	18·33	„ ¼	43·30	„ ¼	75·51	„ ¼	114·68
„ ½	19·10	„ ½	44·32	„ ½	76·09	„ ¼	116·21
„ ¾	19·87	„ ¾	45·35	„ ¾	77·98	„ ¾	117·75
8	20·66	15	46·40	22	79·28	29	119·30
„ ¼	21·46	„ ¼	47·45	„ ¼	80·58	„ ¼	120·86
„ ½	22·26	„ ½	48·51	„ ½	81·90	„ ½	122·43
„ ¾	23·08	„ ¾	49·58	„ ¾	88·22	„ ¾	124·01
9	23·90	16	50·66	23	84·56	30	125·61
„ ¼	24·73	„ ¼	51·74	„ ¼	85·90		
„ ½	25·57	„ ½	52·84	„ ½	87·25		
„ ¾	26·42	„ ¾	53·95	„ ¾	88·61		

SECTIONAL AREAS OF BREAST WALLS.

FOR VARYING VERTICAL HEIGHTS.

Top width 2 feet, Front Slope 1 *in* 2, *Back Slope* 1 *in* 3.

Area = ½ sum of two parallel sides × S.

Vertical height.	Correspond-ing length of S.	Area in square feet.	Vertical height.	Correspond-ing length of S.	Area in sq. feet.	Vertical height.	Correspond-ing length of S.	Area in sq. feet.	Vertical height.	Correspond-ing length of S.	Area in sq. feet.
3	3·354	7·55	10	11·180	31·67	17	19·006	64·92	24	26·832	107·33
„ ¼	3·633	8·25	„ ¼	11·459	32·69	„ ¼	19·285	66·28	„ ¼	27·111	108·99
„ ½	3·913	8·96	„ ½	11·739	33·73	„ ½	19·565	67·65	„ ½	27·391	110·68
„ ¾	4·192	9·69	„ ¾	12·018	34·79	„ ¾	19·844	69·03	„ ¾	27·670	112·39
4	4·472	10·42	11	12·298	35·86	18	20·124	70·43	25	27·950	114·11
„ ¼	4·751	11·18	„ ¼	12·577	36·93	„ ¼	20·403	71·32	„ ¼	28·229	115·82
„ ½	5·031	11·95	„ ½	12·857	38·03	„ ½	20·683	72·28	„ ½	28·509	117·57
„ ¾	5·310	12·72	„ ¾	13·136	39·13	„ ¾	20·962	74·66	„ ¾	28·788	119·32
5	5·590	13·51	12	13·416	40·25	19	21·242	76·11	26	29·068	121·09
„ ¼	5·869	14·31	„ ¼	13·695	41·36	„ ¼	21·521	77·54	„ ¼	29·347	122·87
„ ½	6·149	14·96	„ ½	13·975	42·50	„ ½	21·801	79·00	„ ½	29·627	124·67
„ ¾	6·428	15·94	„ ¾	13·254	43·65	„ ¾	22·080	80·48	„ ¾	29·907	126·47
6	6·708	16·77	13	14·534	44·80	20	22·360	81·97	27	30·180	128·29
„ ¼	6·987	17·61	„ ¼	14·813	45·96	„ ¼	22·639	83·64	„ ¼	30·465	130·09
„ ½	7·267	18·46	„ ½	15·093	47·15	„ ½	22·919	84·98	„ ½	30·745	131·92
„ ¾	7·546	19·33	„ ¾	15·372	48·34	„ ¾	23·198	86·50	„ ¾	31·024	133·77
7	7·826	20·21	14	15·652	49·55	21	23·478	88·04	28	31·304	135·64
„ ¼	8·105	21·10	„ ¼	15·931	50·77	„ ¼	23·757	89·68	„ ¼	31·584	137·48
„ ½	8·385	22·00	„ ½	16·211	52·00	„ ½	24·037	91·12	„ ½	31·863	139·36
„ ¾	8·664	22·91	„ ¾	16·490	53·24	„ ¾	24·316	92·69	„ ¾	32·142	141·26
8	8·944	23·84	15	16·770	54·50	22	24·596	64·27	29	32·422	143·17
„ ¼	9·223	24·78	„ ¼	17·049	55·75	„ ¼	24·875	95·84	„ ¼	32·701	145·09
„ ½	9·503	25·73	„ ½	17·329	57·02	„ ½	25·155	97·45	„ ½	32·981	147·02
„ ¾	9·782	26·69	„ ¾	17·608	58·31	„ ¾	25·434	99·06	„ ¾	33·260	148·97
9	10·062	27·67	16	17·888	59·62	23	25·714	100·69	30	33·540	150·93
„ ¼	10·341	28·65	„ ¼	18·167	60·91	„ ¼	25·993	102·33			
„ ½	10·621	29·64	„ ½	18·447	62·24	„ ½	26·378	103·98			
„ ¾	10·900	30·65	„ ¾	18·726	63·57	„ ¾	26·552	104·65			

APPENDIX 2.

NOTES ON OILING ROADS IN BOMBAY, DELHI, ALLAHABAD.

Note by MR. J. MACKESON, B.SC., A.M.I.C.E., *Executive Engineer, Bombay Municipality.*

This municipality have experimented with different dust preventives during the past ten years. The materials tested were Westrumite, Erminite, Calcium Chlorate, Sodium Chlorate, Crude Petroleum, Tar, and Akonia. All these materials, except Crude Petroleum Tar, and Akonia, have failed to give entire satisfaction. Crude Petroleum with an admixture of 5 per cent. of distilled tar has given satisfaction so far as dust-laying is concerned.

2. The roads treated therewith present a neat appearance and a very smooth surface is obtained. It also protects the road surface to a certain extent, thus reducing its wear, though this department has no means of ascertaining at present how much saving can be effected in road repairs by this application. The treatment of road surface thus effected is much appreciated by the public especially the tradesmen.

3. The Crude Petroleum which had been used by this municipality was obtained from Messrs. W. and A. Graham and Company of Parsi Bazar Street, Fort, Bombay, who describe the article "Liquid Fuel."

4. The oil when purchased about eight years ago was paid for at Rs. 30 (thirty) per ton. The rate was subsequently increased to Rs. 33-12 per ton and finally this municipality had to pay Rs. 40 per ton, probably for the reason that it cannot be had from any other firm. When, however, a higher rate than the last one was demanded further treatment with crude oil was suspended.

5. The procedure adopted in the work is to thoroughly repair the road where necessary and allow it to set sufficiently under ordinary traffic and sweep the surface carefully before the oil is applied to it. The oil was brought from the Company's installation in ordinary watering carts which are twice passed over the surface to be coated with oil so as to get an even sprinkling. The men then follow the carts with the ordinary flat bamboo broom and brush the surface until every part of the road is covered with oil, but without any surplus or pools.

6. Sunday is the day usually selected for the purpose and only half the width of the road is treated at a time, the remaining half being taken in hand for a similar treatment on the Sunday following. Such treatment answers the purpose for about four to five weeks, when another coating of the oil has to be given to the same surface though a less quantity of oil is required for the second coating. A third coating is found necessary about six weeks after the second coating, but with a still smaller quantity of oil.

7. Three or four operations as mentioned answer the required purpose during one dry season, *viz.*, from about the end of October to the break of the monsoon during which no watering is necessary, as dust is not formed on the road on account of the road being generally wet by the rains. It must, however, be stated that much depends on the climatic condition of the place though the foregoing is suited to Bombay.

8. The cost of oiling works out as shown in the following table, taking the cost of oil at Rs. 30, Rs. 33-12, and Rs. 40 per ton of 232 gallons :—

Rate.	Cost per 100 square feet.			Remarks.
	1st coating.	2nd coating.	3rd coating.	
Rs. a. p.	Rs. a. p	Rs. a. p.	Rs. a. p.	
30 0 0	0 5 7	0 4 3	0 3 3	Wages of a coolie 5 annas per day and a pair of bullocks Re. 1-2 per day.
33 12 0	0 6 3	0 5 0	0 3 11	Wages of a coolie 6 annas 9 pies (including grain compensation) and a pair of bullocks at Re. 1-6 per day and 2½ per cent. distilled tar.
40 0 0	0 7 0	0 6 0	0 5 11	Ditto ditto.

9. On account of the higher price demanded for it from time to time as also its inefficacy on a freshly-metalled surface where the crude petroleum worked as a lubricant instead of binder and loosened the road surface, it had to be abandoned. Distilled tar obtained from gas works has been used during the past four years with complete success. The process consists of thoroughly sweeping the road surface and clearing all the dust therefrom before the distilled tar, boiled in special boilers, is spread over the road surface. The tar after being spread is covered over with sand and allowed to dry before traffic is permitted over it. After the tar has sufficiently dried and the sand is reduced to dust, the dust is also swept off. This tar painting process is used when the road surface is in tolerably good condition and not requiring repairs. In cases where the road requires to be repaired and process consists of scarifying the road surface and bringing it to a uniform level with such addition of metal as may be necessary and rolling same dry over the surface thus prepared so much boiled tar is poured as is necessary to fill in the crevices and the roller passed over same. Sand is then spread over the surface which is again rolled and the tar allowed to dry, any dust therefrom being subsequently removed.

10. The cost per 100 square feet for the former process, *i.e.*, upon a road in good condition, is about Rs. 1·75 and that for the latter exclusive of the new metal is Rs. 6·60.

11. Where the road surface has been tarred, no watering is required, and cleansing operations are greatly facilitated.

12. As tar was not available, I ordered from England Akonia in order to keep down the dust on the roads traversed by the procession during the Royal visit. Akonia Powder has been used with great success in England and is very simply applied. The road has to be swept clean and after slight watering the powder is sprinkled over the surface. The powder may also be dissolved and applied by means of a water cart. This powder is a preserver of the road as well as a dust preventor and does not injure the paint of carriages or the feet of horses. Owing to the hydroscopic character of the powder, the road is kept moist. The powder solution is required to be applied about three times a month, but in decreasing quantities. The cost of Akonia delivered free at the Docks, Bombay, is Rs 100 per ton.

13. One mile of roadway 60 feet wide requires about 5 tons of Akonia for the first dressing, and if three dressings be given during the first month 15 tons will be required. Only half the above quantity will be required for the second and third months and for the remaining five months, that is, excluding the monsoon months, about 20 tons will be required, or in all 50 tons per annum. This works out at about 2¼ annas per square yard per annum. This powder has been well tested during the Royal visit and has proved very satisfactory. It is again being made use of to a greater extent to save fresh water, of which there is a scarcity at present, and to lay dust efficiently which cannot be attained with ordinary watering.

14. The municipality have again been able to obtain distilled tar in sufficient quantities and some of the principal roads are being treated therewith. The surface of the road after being tarred is covered with chips varying in size from ¾" to 1" according to circumstances of the case and then rolled with a heavy steam roller.

II.

Note by Mr. F. T. Jones, M.V.O., Assistant Engineer, Public Works Department, United Provinces.

DELHI DARBAR, 1911.

OILING CERTAIN MAIN ROADS.

Report.

1. The idea in laying down oil on the road surface is, that after the oil contained in the liquid fuel is consumed (partly by evaporation and by absorption by the road metal), the asphalt basis of the fuel remains to make the surface more adhesive and elastic, and to preserve the life of the road against the wear and tear caused by crumbling away action which causes mud or dust, as the case may be. A road thus oiled is benefited in two ways :—

(i) It does not require watering in dry weather, since it is rendered absolutely dustless.

(ii) It does not need repairs for a considerable time (according to the number of coats of oil applied and the amount of traffic), as the wear of the metal is less and more evenly distributed.

That oiled roads are dustless, have been satisfactorily proved in India, in Presidency towns, at the Allahabad Exhibition, and fully demonstrated at Delhi during the Darbar period, where troops on the march and the enormously heavy wheel traffic raised no dust whatever.

2. In this last case 85·25 miles of road, varying in width from 12 to 60 feet, with an area of over half a million square yards, were oiled with two or three coats, only a few roads receiving but one coat.

4. Work was carried out in two sections. The city section working from Sabzimandi station and doing all oiling in the city and civil lines, and the camp section working from Kingsway and doing all oiling in the camp area. One tank wagon containing about 3,300 gallons of liquid fuel supplied by the Asiatic Petroleum Company was delivered at each station every day. The oil was generally pumped direct into the carts (ordinary watering carts with the sprinklers removed) by which it was taken on to the road, but in order to guard against irregularity in arrival of the wagons or disposing of their contents, storage of 5,000 gallons at Sabzimandi and 7,000 gallons at Kingsway was provided. At each station there was a mistry, supplied by the Asiatic Petroleum Company, whose duty was to adjust the pump on the tank wagons and to make all repairs to the valves of the watering carts which are continually getting out of order ; there were also six men for filling the carts.

When the coolies were employed, the services of two non-commissioned officers and six sepoys of Pioneers were obtained to take charge of the spreading of the oil, and were assisted by a certain number (eventually seven) of *ex*-sepoys, who proved of the greatest use, both on the spreading and in detached work for which their intelligence and habit of obedience made them far more fitted than any ordinary mates or jamadars.

At the commencement of the work, the bullockmen, who were paid at daily rates, being taken from watering roads and accustomed to work in the morning and evening gave a lot of trouble; they turned up after and went away before the Pioneers, move very slowly, and had to have sepoys with them to prevent their running away. After a fortnight of this kind of worry had been put up with, piece-work payment was introduced. On bringing up a full cart-load of oil, the carter received from the native officer or N.-C. O. in charge a

ticket valued at 6, 8, 10 or 12 annas according to the distance covered, the value being adjusted so that each man could easily earn about Re. 1-8 a day. Every two or three days the tickets were collected, checked, paid for, and destroyed. The inauguration of this system practically ended all trouble with the cartmen.

5. Storage tanks of about 600 gallons capacity for the liquid fuel (petroleum residuum) are the most convenient for the purpose and the liquid is run straight from the railway tank wagons or pumped up into them, six storage tanks being required to take the ordinary capacity, of each railway tank wagon, which is about 3,300 gallons. A railway tank wagon can be emptied conveniently in about 24 hours, so that a sufficient number of storage tanks should be available, otherwise demurrage charges will accrue and will add considerably to the cost of operations.

Ordinary cylindrical road watering tank carts of 120 gallons capacity with the sprinklers removed are suitable to pour the fuel on to the road surface. A large four-wheel tank cart of 350 gallons capacity was also found useful as a temporary depôt cart.

For each section of operation four tank carts are required, so that while two carts are being emptied the other two carts are being filled and no time is lost in waiting: each section of road oiled should be commenced at either end: two carts can thus be employed at one and the same time. This method gives the quickest results.

Eight Bass brooms obtained from the Cawnpore Brush Factory can be satisfactorily used with each tank cart, the average half width of roadway being 10 feet. This allows four men to work in a row immediately behind the tank cart and four behind these to carry forward any oil that would possibly lodge or run off.

Only sixteen broom handles are necessary, the same being fixed into new broom heads when the old ones are worn out. A broom handle ought to be about four feet long. The broom head lasts about 10 days in the operation with ordinary care. It is necessary to have three dozen broom heads per section of road in stock so as to replace without delay those that wear out. Ordinary sweepers' brushes sweep much cleaner than brooms.

The valve of the cart being raised, the oil is allowed to run out in sufficient quantity to spread itself over the width of roadway. The valve is then shut off and the cart moved on to allow the brooms to play: the half width of roadway is thus smeared with the oil. After this, as before stated, four brooms in front and four behind are applied to give the road an even coating of oil, and at the same time to prevent lodging of superfluous oil which does not work in and leaves pockets of excess oil. Immediately that quantity of oil is sufficiently and evenly spread over the roadway, the tank cart valve is again opened and the process continued as before. The oil should be let out from the cart on the last patch of oil already spread; if dropped too far forward it has to be pulled back and time is lost.

In order to prevent the formation of pools, the road should be oiled before ruts have had time to form; it is very convenient to oil the road immediately after making it and before opening it to traffic. As the oil naturally tends to run down into the gutters, it should be dropped on the crown of the road, and it is as well to tell off a couple of men to bring along with their brushes all oil that gets into the gutter. Care should be taken to always oil down hill, if possible, so as to make it easy to carry off surface oil.

It is usual to mix 5 per cent. of coaltar with the liquid fuel for the second and third coatings in order to obtain better wearing results, but this method of oiling was not adopted for the Darbar roads, as lasting value was of no consideration and rapidity of execution of the work was essential so as not to block traffic.

6. Sand may be lightly sprinkled over the second and third coatings. At Delhi this was done by means of an ordinary labourer's basket for carrying earth, which after being filled with sand, is shaken up gently (so as not to allow too much sand on any one spot) and the sand allowed to fall through as from a sieve. The object of sand showering is to prevent too much of the fuel being evaporated, and to allow the oil to soak into the road metal. The sand being

heavily loaded with oil does not rise under traffic. As a matter of fact, on the Darbar roads, sand sprinkling was not carried out to any great extent.

7. It is best to close the road to traffic altogether, but if this be not possible then—

(i) The oiling should be done in sections, half the width of the road at a time, so as not to block traffic.

(ii) The oiled portion of the road should be closed to all traffic for 12, 24 and 36 hours for the first, second, and third coats, respectively, to allow the surface to dry.

It is as well when sweeping the road surface to remove the dust well away from the road and deposit it in a ditch or hole.

When admixing tar first mix the tar and oil in a drum to prevent clogging of the pipe in the tank cart, as if a full tin of tar is thrown into the tank cart and when stirred the pipe gets blocked.

For a road one mile long and 12 feet wide the following amount of the liquid fuel is required :—

First coating,	...	...	...	...	10 tons.
Second coating,	...	...	...	...	5 ,,
Third coating,	...	...	...	...	4 ,,
			Total,	...	19 tons.

The cost of the fuel in Calcutta was Rs. 40 per ton. The cost of 19 tons worked out to Rs. 1,130 at Delhi. The rate for purposes of estimation may be taken at 2 annas 6 pies per square yard for three coats or 2 annas for two coats.

The crude oil was supplied at the current market rate per ton f. o. r. Budge Budge in full railway tanks and the unloading and laying operations were carried out by the Public Works Department. It was not considered satisfactory to entrust such work to contractors, as the work was carried on at all hours of the day and night as traffic permitted and supervision would have been difficult and risk of breakdown too great.

Forty-six labourers, with two mates, were required for the work, and were told off as follows :—

Sixteen men on the broom at each end of the section under operations, working in reliefs, eight at a time, controlled by a mate, and four at the storage tanks for filling tank carts with the fuel.

Two men at each end of the section were employed for showering sand, and eight men at each end of the section to sweep off the overlying dust, prior to oiling. The whole gang was supervised by an overseer.

The proportion of coolies employed on sweeping varies according to the amount of dust, from about a quarter up to as much as three-quarters of the total number at work.

8. The following remarks apply only to *kankar roads* which formed practically the whole of the roads oiled at Delhi in connection with the Darbar.

It is essential that the road to be oiled, if it is to carry heavy traffic, should be made of the hardest kankar procurable (especially if traffic is going over it before the oil is quite dry) and the less earth used for blinding the better. If soft kankar is used, the heavy traffic will quickly cut it up, particularly if it is not well set and not quite dry right through.

The surface of the road should be swept quite clear of all dust before the oil is put down, and if the dust is thick, it may be necessary to go over the surface two or three times to get it clean enough. Only where the kankar is very soft and traffic cannot be stopped a little dust can be left without harm.

The first result of not sweeping clean is that the oil takes much longer to soak in, and any cart or foot passing over it picks up the oil and dust together. leaving the bare road surface underneath.

The second result is the dust so left will, as the oil dries up, gradually become a nuisance, whereas a good road swept clean will form little dust.

It is of the utmost importance to oil the side roads to a distance of fully 100 yards from their junction with the road which is being oiled, as otherwise much dust is brought in on to the main road which destroys the effect of the oiling.

The first coat of oil soaks in rapidly if the surface is good, and in many cases traffic may safely be allowed over the road after three or four hours Subsequent coats require very much more time The oil soaks in slowly, and as it dries becomes exceedingly sticky; finally part of it soaks in and the rest dries and forms an asphaltic layer on the road.

Traffic going over the tough surface so formed merely polishes it, making it black and shiny and causing but little wear. If traffic is allowed over the oil before it has dried a large portion of the oil is carried away on the mud guards and the rest forms with whatever dust there may be, a thick black mud. As it dries this mud turns into a paste which does not adhere to the wheels of vehicles, and is gradually rolled by them into the road forming a good surface ~~smooth~~ and black. This paste, however, is not truly incorporated with the road, and as it gets drier, it blisters and flakes away leaving the road covered with a soft oil-impregnated covering which, in a comparatively short time, is pounded up into heavy dust.

9. Nearly all the Darbar roads oiled were of this type, as the three days' rain which occurred in the middle of November, when most of the main roads had received their second coat, made it necessary to give another coat at a time when traffic was so heavy that it was quite impossible to close the main roads. Ridge and Flagstaff roads alone showed the results which might be expected under normal conditions, and these remained nearly as good as ever after four months' light wear.

It must be remembered that the oiling at Delhi was carried out under very severe conditions. In many cases roads could not be closed, and being done by halves, it was quite impracticable to barrier off the road for perhaps a mile or more so that traffic could not be kept off the newly-oiled road, particularly at night. Even where a road could be closed by day, it was impracticable to erect permanent barriers, and temporary ones even with chaukidars proved quite useless after the police had gone off duty at 8 p.m.

Traffic going over a road on which the oil had reached the sticky stage had another, sometimes a most serious, effect It tended to pick out lumps of kankar in some cases leaving the road in a deplorable state, honey-combed with holes or lined with deep ruts. This tendency showed itself very greatly, on one or two pieces of recently-made stone roads which were oiled, and where the consolidation had not set as well as in the case of a kankar road.

10. Oiling appears to be attended with one great disadvantage; it cannot stand heavy rain and traffic combined, as the road then becomes covered with a thick glue-like mud, and loses a large portion of its oil which appears to be washed out by the rain. The effect of the heavy rain experienced at Delhi in the middle of November went particularly to destroy the effect of the second coat of oil on all the main roads. The Chauburja road alone showed comparatively little damage, while the Ridge road, on which traffic was light, appeared quite unaffected by reason that these roads were built on a rock foundation and being also undulating and well drained the water ran off quickly; many of the main roads, however, became flooded and water-logged

In addition to the metalled portion of the roads the "*kachha*" sides of many roads were also oiled. In this case no sweeping was done; the oil was merely spread thickly over the dust and natural earth, and allowed to soak in and be incorporated by traffic. This method is very expensive in oil, but proved perfectly effective, a second coat of oil being rarely required. The object was merely to lay the dust with a very slowly evaporating substance instead of with one which evaporates quickly, as water does. But in many cases the oil had a distinctly consolidating effect, and thus added to the travelling width of the road.

It should be noted that the ground must be absolutely dry before any oil is put on. The great advantage of oiling the unmetalled road sides is that there is no dust, which ordinarily lies there, to get blown on to the oiled surface, or conveyed on to it by wheeled or foot traffic and spoil the effects to the oiling by lying over it; it is greatly due to this precaution that in a windy dusty place like Delhi the road surfaces remained clean.

Oiling was also found most useful on the raised side walks which were made of rammed earth and given a covering coat of oil, which not only consolidated them and effectually laid the dust, but made a pavement preferred by the natives walking over it in bare feet.

Oil was also laid on the track of the Darbar light railway with excellent results, as, in spite of open carriages with low wheels and a continuous service of trains, there was no dust on the line.

Note by RAI BAHADUR PANDIT HARI KISHEN PANT, *Executive Engineer, Public Works Department, United Provinces.*

OILING ROADS IN THE UNITED PROVINCES EXHIBITION.

The total length of metalled roads in and around the United Provinces Exhibition grounds was about four miles and the width 12 feet. The metal on all the roads treated with oil was kankar.

About half the length of the roads was newly made specially for the Exhibition and had not consequently had sufficient time to settle down.

The result was very satisfactory eliminating all dust and the roads were free from it during the whole of the period (from November, 1910, to May, 1911). The largest amount of traffic was during December, 1910, and January and February, 1911.

The old roads were much better than the new ones which, not having good foundations, did not keep the surface smooth during wet weather and were somewhat sticky; but this cannot fairly be put down as the fault of the oiling.

During the seven months these roads were used, they showed very little wearing of the surface, and I think the oiling will prolong the life of the metal.

According to the manager (Mr. Harlow) of the Asiatic Petroleum Company, who personally helped in supervising the oiling of the roads, 19 tons of crude oil are required for oiling one mile of 12′ wide road. The first coat takes ten, the second five and third four tons.

At the Exhibition oil was supplied free of cost by the Asiatic Petroleum Company and the cost of labour came to about Rs. 250 for one mile of 12′ road including cost of sand which was sprinkled over the oiled surface.

The road to be oiled ought to have a smooth surface and to have a good camber, say, 1 in 36, and the surface ought to be well swept before the oiling is done.

The cost of crude oil in Calcutta is Rs. 40 per ton and allowing Rs. 10 for carriage, the cost will be $19 \times 50 =$ Rs. 950 for oil and Rs. 250 for labour = Rs 1,200 for a mile of 12′ wide.

The following method was employed for oiling the roads at the Exhibition :—

Material.—Oil storage.

Storage tanks of 600 gallons capacity for liquid fuel (petroleum residuum) were used for the purpose in which the liquid fuel from the railway tank waggons was stored. There was a double advantage in storing the fuel in this manner:—

(1) The tanks being of circular section could be rolled without much difficulty as conveniently near as possible to the particular road being oiled, providing a minimum length of lead.

(2) To prevent demurrage by retaining the railway tank waggon longer than legitimately allowed by the railway authorities. (A railway tank waggon can be emptied conveniently in 24 hours).

Tank carts.—Ordinary road watering tank carts of semi-circular section 4′ by 4′ in diameter were utilized to shower the fuel on the roads.

Four tank carts were in use so that while two carts were being emptied, the other two carts were being filled in order that no time might be lost in replenishing the carts. Each section of road oiled was commenced at either end thereby employing two carts at a time. This method saved the trouble of diverting traffic to a great extent as barriers were frequently ignored.

Bass brooms.—Eight Bass brooms were satisfactorily used at each tank cart, the average width of roadway being 12′; this allowed four men to work in a row immediately behind the tank cart and four behind these to carry forward any oil that would possibly lodge.

Only sixteen broom handles were necessary, the same being fixed into new broom heads when the old ones wore out. Broom handles ought to be about 4′ long. A broom head lasted about ten days in the operation with ordinary care. In the beginning owing to a paucity of broom heads, work did not progress very satisfactorily. It is necessary to have, say, about three dozen broom heads in stock so as to without delay replace those that wear out.

Method of oiling first coating.—The valve of the cart being raised, the oil is allowed to run through the perforated pipe until a sufficient quantity to be spread over the width of roadway has been let out. The valve is then shut off and the cart moved on to allow the broom play, so that the whole width of roadway might be smeared with the fuel. After this, as before stated, four brooms in front and four behind were exercised to give the road an even coating of oil, and at the same time to prevent lodging of superfluous oil, which if not done, causes the road to look patchy and unsightly. Immediately that quantity of fuel is sufficiently and evenly spread over the roadway, the tank cart valve is again opened and the process continued as before.

Second and third coating.—Five per cent. coaltar is mixed with the liquid fuel for the second and third coatings. The method of oiling is the same as for the first coating.

The tar was mixed with the oil in the following way :—

A five-gallon kerosine oil tin was half filled with tar and the remainder with fuel; the whole was stirred well and then poured into the tank cart, the same was repeated once for the same cart and then the contents of the cart were well stirred before emptied on the road.

Sand showering.—Sand must be showered over the first and third coatings only. This was done by means of an ordinary labourer's basket for carrying earth, which after being filled with sand was simply shaken gently (so as not to allow too much sand on any part) and the sand allowed to fall through as from a sieve. The sand was conveyed to the site in an ordinary *thela*. The object of sand showering is to prevent too much of the fuel being evaported and to duly soak the road metal.

Personnel.—Forty-six labourers, including two mates, were employed for the work and were told off as follows :—

Sixteen men on the brooms at each end of the section under operations working in reliefs, eight at a time, controlled by a mate, and four at the storage tanks for filling tank carts with fuel. Two men at each end of the section were employed for showering sand and three men at each end of the section to sweep off the overlying dust prior to oiling. The whole gang was supervised by an overseer.

Notes from observation

1. Roads ought to be closed to all traffic for at least 36 hours in these parts to allow the surface to dry.

2. To give satisfaction the wheel marks on the road oiled ought to appear dark and smooth like glue.

3. The idea of mixing the tar as stated was to prevent clogging of the pipe in the tank cart. Previously a full kerosine oil tin of tar was thrown into a tank cart and then stirred; this caused clogging of the holes in the pipe. The holes in the pipe are bored on the outer side of the pipe; if bored at the bottom they would not allow any tar to clog.

4. The tank carts were filled with the liquid fuel by means of kerosine oil tins improvised as buckets with a wooden lath across the top to which a rope was fixed so as to lift the tins when filled with oil and let them down the side of the storage tanks.

5. Four hundred feet of 12′ road took one tank cart of liquid fuel for one coat with a satisfactory result. To spread the same over a large area does not allow a *kankar* road sufficient fuel for soaking; such roads are slow in absorption. For a road one mile long and 12′ wide the following amount of liquid fuel is required :—

First coating ten tons, second coating five tons and third coating four tons.

APPENDIX 3.

GENERAL DIRECTIONS AND SPECIFICATIONS RELATING TO THE TAR TREATMENT OF ROADS.

ROAD BOARD SPECIFICATION No. 1.

General directions for surface tarring.

1. Surface tarring may be advantageously applied either to an old road surface in good condition or to a new surface after it has been consolidated and tried, but the tarring should never be carried out unless the road is thoroughly dry.

If there are any depressions, pot-holes, waves, grooves or other irregularities, these should, as far as practicable, be made good before tarring is commenced, so as to provide an even surface.

2. Painting and spraying machines get through the work of tarring more rapidly than application by hand, and consequently are to be recommended, but hand work gives satisfactory results, and the selection of the method to be employed must be largely determined by the available supply of efficient labour.

3. If it is intended to tar an old surface, it is advisable to take advantage of the early months of the year to scrape or brush the road during wet weather as a preparation for subsequent tarring, and especially to keep the road free from caked mud. 5.5.12.

4. If the crust of a road is thin at the sides, but adequate in the centre, the sides should be strengthened and consolidated before application of tar to the surface.

5. In re-surfacing any road the surface of which is afterwards to be tarred, stone chippings, and not fine material, should be used for binding.

6. The road, whilst being tarred, should be closed to traffic over half its width, or, where practicable, over its whole width.

7. The road should be thoroughly brushed and cleaned before application of the tar. Wet brushing should be used some time previous to dry brushing if there is any caked mud. Any method of brushing may be used which will scour and clean the road thoroughly, the best being horse brushing, followed by hand brushing.

8. Tar should be used for surface tarring which complies with either Road Board Specification for tar No. 1 or Road Board Specification for tar No. 2; but if the heavier grade of the tar is used, care should be taken to apply it only when the road is dry and well warmed by the sun's rays, otherwise it will not flow freely.

9. The tar should be heated to its boiling-point at convenient positions on the works, and should be applied as hot as possible, so that it may flow freely. The desired temperature will be generally found in practice to lie between 220° and 240° F for tar No. 1, and between 260° and 280° F. for tar No. 2.

10. In order that the tar should be applied to the road as hot as possible, it is advisable, if the method of application is by hand, to use flexible pipes to convey the tar from the boiler to the point of application. If these are not available, it will be found convenient, in case of hand pouring, to use 8-gallon cans specially constructed for the purpose, fitted with spouts leading direct from the bottom of the cans, and being not less than 1½ inches in diameter at the orifice.

11. Immediately on application the liquid tar should be brushed, so far as necessary, to ensure regularity in thickness of the coating.

12. The quantity of tar required will vary according to the physical conditions of the road, but generally, in the case of a road to be treated with tar for the first time, the quantity should be 1 gallon to coat from 5 to 7 superficial yards.

13. If the road must be opened for traffic before the tar has set hard, grit should be spread on the surface to prevent the tar from adhering to the wheels of vehicles, but gritting should be delayed as long as possible, and the quantity of gritting material to be spread should be no more than sufficient to prevent the tar from adhering to wheels. Stone chippings, crushed gravel, coarse sand or other approved material (free from dust) not larger than will pass through a ¼-inch square mesh, should be used for gritting, in quantity not exceeding 1 ton for 300 to 350 superficial yards, if grit is used, and 1 ton for 200 to 250 superficial yards, if coarse sand is used

14. Precautions should be taken to prevent liquid tar passing directly through drainage gratings or outlets

15. For the safety of the public precautions should be taken by lighting, watching and warning.

Notice boards should be placed in suitable positions bearing in large letters printed in conspicuous colours the following words; --

CAUTION.

TARRING IN PROGRESS.

CYCLISTS ADVISED TO WALK.

It is specially desirable to place warning notices at points in the neighbourhood of the work where other roads join or cross the road being tarred, to enable motorists and cyclists to avoid the obstructed road by taking any available alternative route.

16. On heavily trafficked roads it is advisable to apply a second coat to either the whole width or from 9 to 12 feet of the centre of the road in quantity of 1 gallon to coat from 8 to 10 superficial yards about two to three months after the first application.

17. Surface tarring should be renewed annually on all important roads and as required on roads with light traffic. On such recoatings the quantity of tar to be applied will vary with the extent to which the previous coating of tar has been removed by weather or by traffic.

18. Two or more samples of the tar used should, in all cases, be kept in quart tin cans and be carefully labelled, including particulars fixing the locality or length of the road on which the tar was used. The Road Board will arrange with the National Physical Laboratory to submit a selection of these samples to a series of chemical and physical tests with a view to the results being recorded for future reference, and surveyors will, from time to time, be invited to send samples for the purpose.

19 In all cases careful record should be kept of the condition of the road surfaces in winter and summer, both before and after tarring, the quantity and quality of tar used, the superficial area covered, the state of the weather when the work is being done, the time occupied in actual work, and in waiting whilst work is stopped owing to wet weather, the number of men employed, and full details of the cost of labour and material.

20. Surveyors are invited to send records to the Road Board to be classified and published for general information. Forms for these records will be suplied by the Board.

21. Surveyors are recommended to have samples of the tar supplied to them under contracts properly tested by a qualified analytical chemist for—

(1) Specific gravity.
(2) Freedom from water.
(3) Fractionation.
(4) Free carbon.

NOTE.—These general directions are not intended to displace, or to discourage the use of proprietary articles, of which here are several of proved value.

ROAD BOARD SPECIFICATION NO. 3.

General directions for surfacing with tar macadam.

1. Any road which is to be surfaced with tar macadam should have a proper foundation or sub-crust of adequate thickness to bear to traffic likely to use it.

2. Before laying a new surface of tar macadam, the thickness of the old crust, including foundation, should be ascertained by opening trial trenches at intervals averaging about 150 yards extending from the haunch of the road to the centre, such trenches to be made alternately on opposite sides of the road.

3. The thickness of the surface coating of tar macadam, when consolidated by rolling, should be from 2 to 3 inches according to traffic requirement. For a greater thickness than 3 inches, the material should be applied in two coats.

4. In the case of naturally hard sub-soils, not materially softened by infiltration of surface water, the total thickness of the road crust, including foundation, if any, after consolidation of the new surface of tar macadam by rolling, should not, under ordinary circumstances, be less than 6 inches, unless the sub-soil is so hard as in itself to act as a good foundation, in which case the thickness of the road crust may be reduced to 4 inches. In the case of clay or other yielding sub-soils, the total thickness should not be less than 11 inches

5. The finished surface should have a cross-fall of about 1 in 32.

If the crust is not sufficiently thick at the crown to enable this cross-fall to be obtained with a new coating of the thickness above mentioned, then the old surface should be left intact and unscarified, and the thickness of the new coat of tar macadam increased as far as may be necessary.

If the crust is of sufficient thickness for the purpose, the regulation of the cross-fall should be carried out by scarifying the surface and removing material from the crown to the sides previous to the application of the new coating. The material loosened by scarifying should be screened and all finer material than ½ inch should be thrown aside.

6. The aggregate of the new surface of tar macadam should be composed of broken stone of approved quality, or selected slag of approved quality, and should contain at least 60 per cent. broken to the size of 2½ inches, not more than 30 per cent. of from 2½ inches to 1¼ inches, and 10 per cent. of ¾ inch to ½ inch for closing. The last-mentioned size should be kept separate and used as top dressing during rolling operations.

7. The stone used must be thoroughly dried before being coated with tar.

8. For making tar macadam, tar should be used which complies with Road Board Specification tar No. 1, or Road Board Specification tar No. 2, the choice being determined by the circumstances of each case.

If tar No. 1 has been used for tarring the stone, care should be taken, especially in hot weather, that the tarred material has been allowed to stand for a sufficient length of time to allow the tarred surface of the stones to become partially hardened and in a tacky condition.

If tar No. 2 has been used for tarring the stone, the macadam should be laid soon after being tarred; and if the tar be of the heavier grade of this quality, the stone coated with such tar should only be laid when the road is quite dry and in warm sunny weather.

9. The quantity of tar used to coat 1 ton of stone should be approximately from 9 to 12 gallons, varying according to the sizes of the stone, the grade of tar used, the method of mixing and other conditions.

10. The tar macadam, after having been spread and levelled, should be rolled into a smooth, surface, but too much rolling should be avoided

Less rolling is required than in the case of water-bound macadam.

A 10-ton roller is a suitable size for use in most cases, but good results can be obtained by using a 6-ton roller and finishing with a 10-ton roller.

11. In order to get the best results from the use of tar macadam, it is advisable to apply a coating of tar to the surface after the road has been used by traffic for several weeks. This tar should comply with the provisions of Road Board Specification for tar No. 2, and should be poured or sprayed on the surface at a temperure of about 270°F.

12. Stone chippings, crushed gravel, coarse sand or other approved material (free from dust) not larger than will pass through a ½-inch square mesh, should be used for gritting in quantity not exceeding 1 ton for 300 to 350 superficial yards, if grit is used, and 1 ton for 200 to 250 superficial yards, if coarse sand is used.

NOTE.—These general directions are not intended to displace or to discourage the use of proprietary articles, of which there are several of proved value.

ROAD BOARD SPECIFICATION No. 3.

General directions for surfacing with pitch-grouted macadam.

1. Any road which is to be surfaced with pitch grouted macadam should have a proper foundation or sub-crust of adequate thickness to bear the traffic likely to use it.

2. Before laying a new surface of pitch-grouted macadam, the thickness of the old crust, including foundations, should be ascertained by opening trial trenches at intervals averaging about 150 yards extending from the haunch of the road to the centre, such trenches to be made alternately on opposite sides of the road.

3. The thickness of the surface coating of pitch-grouted macadam when finished and consolidated be rolling should be 2½ inches to 3 inches. (except on very light traffic roads when the thickness may be 2 inches) for single pitch-grouting, and from 4 inches to 4½ inches for the double pitch-grouting hereafter described.

4. In the case of naturally hard sub-soils not materially softened by infiltration of surface water, the total thickness of the road crust, including foundation, if any, after consolidation by rolling of the new pitch-grouted surface, should not, under ordinary circumstances, be less than 6 inches, unless the sub-soil is so hard as in itself to act as a good foundation, in which case the thickness of the road crust may be reduced to 4 inches. In the case of clay or other yielding sub-soils, the total thickness should not be less than 11 inches.

5. The finished surface should have a cross-fall of about 1 in 32.

If the crust is not sufficiently thick at the crown to enable this cross-fall to be obtained with a new coating of the thickness above mentioned, then the old surface should be left intact and unscarified, and the thickness of the new coat of tar macadam increased as far as may be necessary.

If the crust is of sufficient thickness for the purpose, the regulation of the cross-fall should be carried out by scarifying the surface and removing material from the crown to the sides previous to the application of the new coating. Material loosened by scarifying should be screened and all material finer than ½ inch should be thrown aside.

6. The aggregate of broken stone to form the new surface of pitch-grouted macadam should contain broken stone of approved quality, of which at least 60 per cent. must be broken to the size of 2½ inches, and 35 per cent. to sizes graded from 2½ inches to 1¼ inches. In addition to this, 5 per cent. of chippings of the same stone, varying from ¾ inch down to ⅜ inch, should be used for closing after the grouting with melted pitch.

7. For making pitch-grouted macadam, the pitch used should comply with the Road Board Specification for pitch, its viscosity being altered to suit climatic and local conditions by varying the quantity of the tar oils as specified therein.

8. It is important that the pitch should not be poured if the surface of the stone is wet. The stone may be protected by tarpaulins, or, wet, may be dried *in situ* by portable blowers or other means.

9. The quantity of pitch required to grout a single coating is, approximately for a consolidated thickness of 2 inches, 1¼ gallons per superficial yard, for 2½ inches, 1½ gallons per superficial yard, and for 3 inches, 2 gallons per superficial yard; but these quantities may vary with different materials, and care must always be taken to fill the voids adequately.

10. The aggregate after having been spread and levelled must be rolled down dry until the surface is formed, but without the addition of any small material.

11. The pitch, after being carefully melted as described in clause 18, must be raised to a temperature of 300°F. Clean, sharp sand must be heated on sand heaters to a temperature of 400°F. A dandy, or portable mixing vessel, is then to be filled with equal parts, by measurement, of the heated pitch and the hot sand, and the mixture, hereafter called the matrix, is to be kept well stirred while it is being emptied from the dandy or portable mixing vessel into pouring cans of from 2 to 3 gallons capacity, which are used for pouring the matrix on to the roadway. Not only during the process of mixing, but afterwards, right up to the time of actual pouring, the matrix must be kept well stirred. The matrix prepared with pitch in the quantities specified in clause 9 should be sufficient to fill the voids of the aggregate.

12. The final rolling should be commenced immediately after pouring the pitch matrix, and carried on rapidly before the matrix has time to set. The 5 per cent. of graded chippings should be spread over the grouted surface in part previously to and the remainder during the process of rolling. The traffic may be allowed on to the finished surface as soon as the surface has cooled to the normal temperature.

Double pitch-grouting.

13. When the traffic is so heavy that a consolidated thickness of from 4 inches to 4½ inches of pitch-grouted macadam is required, it is desirable in order to obtain the best and most economical results, to divide the coating into two layers, the bottom layer to be the thicker one and to consist of large stones, the two layers being rolled down and grouted separately. Any local stone which can be procured cheaply may, if suitable in quality for foundation work, be used for the bottom layer graded from 3-inch gauge down to 2-inch gauge. No chippings are required for finishing the rolling of the bottom layer.

The aggregate for the upper layer should consist of hard road stone of approved wearing quality, broken to 1½ inch gauge, and 5 per cent. of chippings of the same stone used for the upper layer, graded from ⅝ inch down to ¼ inch should be added before and during the process of rolling, and rolled down so as to form the finished surface of the road.

14. In pouring the pitch on the bottom layer, the surface of the pitch should not be brought to the surface of the stone, but should lie about ½ inch below such surface, with the object of providing a key for the upper layer.

15. The materials and the methods of grouting and laying down in the case of double pitch-grouting should, except when otherwise expressly stated, conform to the provisions of clauses 7, 8, 10, 11 and 12.

16. The quantity of pitch required for double pitch-grouting is, approximately for a consolidated thickness of 4 inches, 2¾ gallons per superficial yard, and for 4½ inches, 3¼ gallons per superficial yard, but these quantities may vary with different materials, and care must always be taken to fill the voids in the surface coating adequately.

17. For the purpose of accurately ascertaining the proportions necessary for the matrix, it is essential that portable weights, scales and measures be provided, and all materials used in the preparation of the matrix should be accurately proportioned by weight or measurement.

Instructions for melting the pitch

18. The pitch boilers of from two to three tons capacity should be charged with pitch and about one-half of the proper proportion of tar oils. The fire should then be lighted, and thereafter a steady fire, with fire doors closed, should be maintained, when, in from four to five hours, the pitch should be thoroughly melted. A bright fire should be kept until the pitch reaches a temperature of 300°F. when the remainder of the oils should be added and the mixture thoroughly stirred, the fire doors should then be opened and the temperature of the melted pitch permitted to fall to 250° or 270°F. The pitch should then be ready for use, and in all cases should be thoroughly well stirred before being drawn off.

In the event of bad weather stopping the work of grouting the fire door should be left open, the damper closed, and the temperature of the pitch allowed to fall to 200°F. It can be kept at this temperature for long periods with banked fires consuming about 7 lbs. of coke per hour

It is recommended that a suitable Fahrenheit thermometer with metal protection should be at hand to indicate the temperature of the melted pitch. Whenever the weather is favourable for the re-commencement of the work, the pitch must be again raised to 270°F. by closing the doors and sharp firing.

It is desirable that the boiler should be kept air-tight when the pitch is being melted, by the use of air-tight covers properly packed so as to make an air-tight joint.

NOTE.—These general directions are not intended to displace or to discourage the use of proprietary articles of which there are several of proved value.

ROAD BOARD SPECIFICATION No. 4.

Specification for tar No. 1.

1. **General.**—This tar is suitable for the surface tarring of roads.

As to the use of this tar for making tar macadam, *see* "Road Board general directions for surfacing with tar macadam."

2. **Boiling.**—The tar should be applied as soon as the boiling-point is reached, and over-boiling should be avoided. The desired temperature will be generally found in practice to lie between 220° and 240°F. in the boiler.

3. **Source of tar.**—The tar shall be derived wholly from the carbonisation of bituminous coal, except that it may contain not more than 10 per cent. of its volume of the tar (or distillates or pitch therefrom) produced in the manufacture of carburetted water gas.

4. **Specific gravity.**—The specific gravity of the tar at 15°C. (59°F.) shall be as nearly as possible 1·19, but in view of the great variation in specific gravity of the tar produced in various parts of the country, the specific gravity may be as low as 1·16, or as high as 1·22, provided that, in other respects, it complies with the provisions of the specification

5. **Freedom from water.**—The tar shall be commercially free from water, *i.e.*, it shall not contain more than 1 per cent. by volume of water or ammoniacal liquor, which water or liquor (if present) shall not contain more ammonia, free or combined, than corresponds to 5 grains of ammonia per gallon (= 70 milligrammes per litre) of the tar.

6. **Phenols.**—On vigorous agitation for a quarter of an hour, with twenty times its volume of water at 21° C. (70° F.) the tar shall not impart to the water more than 5 grains of phenoloid bodies, reckoned as phenol, per gallon of water (=70 milligrammes per litre).

Tar from gas works.

The provisions in the following clauses, 7, 8 and 9 apply to tar supplied direct from gas works.

7. **Source of tar.**—The tar shall be solely the natural by-product of the manufacture of illuminating gas (coal gas with or without admixture of carburated water gas), and shall

have been subjected to no other or further treatment than may be necessary for the abstraction of water or ammoniacal liquor and light oils.

8. **Fractionation.**—On distillation the tar must yield below 170°C. not more than 1 per cent. and between 170° C. and 270° Centigrade, not less than 16 per cent. and not more than 26 per cent. of distillate (exclusive of water).

9. **Free carbon.**—The free carbon shall not exceed 16 per cent. of the weight of the tar.

Tar from tar distilleries.

The provisions in the following clauses, 10 and 11, apply to tar supplied from tar distilleries.

10. **Fractionation.**—On distillation the tar must yield below 170° C. not more than 1 per cent. and between 170° C. and 270° C. not more than 26 per cent. of distillate (exclusive of water). The distillate shall remain clear and free from solid matter (crystals of naphthalene, etc.,) when maintained at a temperature of 30° C. for half an hour. The distillation shall be continued to 300° C, and the residual pitch thus obtained shall not amount to more than 73 per cent. of the weight of the tar.

11. **Free carbon.**—The free carbon shall not exceed 16 per cent. of the weight of the tar.

12. **Taking of temperatures.**—The temperature during distillation shall be taken by a thermometer of which the bulb shall be opposite the opening to the side tube of the distillation flask, and the quantities of distillates and free carbon shall be stated in percentages by weight of the portion of tar submitted to distillation.

13. **Dehydrated tar.**—A tar prepared by simple dehydration fulfilling the provisions of this specification may be used with satisfactory results in most cases, but tars from which the naphthalene has been extracted are superior for the purposes of surface tarring.

NOTE.—This specification is not intended to displace or to discourage the use of proprietary articles, of which there are several of proved value.

ROAD BOARD SPECIFICATION No. 5.

Specification for tar No. 2.

1. **General.**—This tar is suitable for surface tarring, and specially recommended for re-tarring, but if the heavier grades of the tar are used, care should be taken to apply it only when the road is dry and well warmed by the sun's rays, otherwise it will not flow freely.

As to the use of this tar for making tar macadam, *see* "Road Board general directions for surfacing with tar macadam."

2. **Boiling.**—The tar is to be applied as soon as the boiling-point is reached, and overboiling should be avoided. The desired temperature will be generally found in practice to lie between 260° and 280°F. in the boiler.

3. **Source of tar.**—The tar shall be derived wholly from the carbonisation of bituminous coal, except that it may contain not more than 10 per cent. of its volume of the tar (or distillates or pitch therefrom) produced in the manufacture of carburetted water gas.

If pitch be added to the tar in order to secure the specific gravity and proportion of residual pitch referred to below, the pitch so added must also have been derived from tar of the foregoing description.

If oil be added to heavy tar or pitch in order to secure the specific gravity and proportion of residue referred to below, the oil so added must be derived from tar of the foregoing description, and must be practically free from naphthalene and tar acids or phenols.

4. **Specific gravity.**—The specific gravity of the tar at 15° C., shall be as nearly as possible 1·21, and in no case shall it be lower than 1·18 or higher than 1·24.

5. **Phenols.**—On vigorous agitation for a quarter of an hour with twenty times its volume of water at 20° C., the tar shall not impart to the water more than five grains of phenoloid bodies, reckoned as phenol, per gallon of water (=70 milligramme per litre).

6. **Fractionation.**—The tar shall be free from water, and on distillation shall yield no distillate below 140° C., nor more than 3 per cent. of distillate up to 220° C. which distillate shall remain clear and free from solid matter (crystals of naphthalene, etc.,) when maintained at a temperature of 30° C. for half an hour.

Between 140° and 300° C. it shall yield not less than 15 per cent., nor more than 21 per cent. of the weight of the tar.

7. **Taking of temperatures.**—The temperatures during distillation shall be taken by a thermometer, of which the bulb shall be opposite the opening to the side tube of the distillation flask, and the quantities of distillates and free carbon shall be stated in percentages by weight of the portion of tar submitted to distillation.

NOTE.—This specification is not intended to displace or to discourage the use of proprietary articles, of which there are several of proved value.

ROAD BOARD SPECIFICATION NO. 6.

Specification for pitch.

1. **General.**—This pitch is suitable for pitch-grouting. *See* "Road Board general directions for pitch-grouting."

2. **Preparation.**—The pitch is obtained by softening the material known as commercial soft pitch, as specified below, by the addition of tar oils, also specified below.

Commercial soft pitch.

3. **Source of pitch.**—The pitch shall be derived wholly from tar produced in the carbonisation of bituminous coal, except that it may contain not more than 10 per cent. of pitch derived from tar produced in the manufacture of carburetted water gas.

4. **Fractionation.**—On distillation the pitch shall yield:—

Below 270° C. not more than 1 per cent. of distillate

Between 270° C. and 315° C. not less than 2 per cent. and not more than 5 per cent. of distillate.

5. **Free carbon.**—The free carbon should not exceed 22 per cent. of the weight of the pitch, but if it be found difficult or unduly expensive to obtain this quality of pitch, a quality containing as much as 28 per cent. of free carbon may be used with a reduced proportion of sand as filler.

6. **Taking of temperatures.**—The temperatures during distillation shall be taken by a thermometer, of which the bulb shall be opposite the opening of the side tube of the distillation flask, and the quantities of distillates and free carbon shall be stated in percentages by weight of the pitch submitted to distillation.

Tar oils.

7. **General.**—The tar oils to be used shall be derived wholly from tar produced in the carbonisation of bituminous coal, or from such tar mixed with not more than 10 cent. of its volume of tar produced in the manufacture of carburetted water gas.

8. **Specific gravity.**—The specific gravity of the tar oil at 20° C. shall lie between 1·065 and 1·075.

9. **Freedom from naphthalene.**—The tar oils after standing for half an hour at 20° C. shall remain clear and free from solid matter (crystals of naphthalene, etc.,).

10. **Fractionation.**—The tar oils shall be commercially free from light oils and water, *i.e.*, on distillation shall yiled not more than 1 per cent. of distillate below 140° C.

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The amount of distillate between 140° C. and 270° C. shall lie between 80 per cent. and 50 per cent.

11. **Taking of temperatures.**—The temperatures during distillation shall be taken by a thermometer, of which the bulb shall be opposite the opening to the side tube of the distillation flask, and the quantities of distillates shall be stated in percentage by weight of the oils submitted to distillation.

12. **Proportions.**—The proportions by weight in which the pitch and tar oils are to be mixed shall be as follows:—

Pitch—88 per cent. to 90 per cent.

Tar oils—10 per cent. to 12 per cent.

NOTE.—This specification is not intended to displace or to discourage the use of proprietary articles, of which there are several of proved value.

APPENDIX 4.

EXTRACTS FROM REVISED RULES FRAMED UNDER THE INDIAN MOTOR VEHICLES ACT, VIII. OF 1914.

I.—PRELIMINARY.

Short title, extent, and definition.

1. (1) These rules may be called the Motor Vehicles Rules, 1914.

(2) They shall extend to the whole of the United Proinces of Agra and Oudh.

(3) In these rules—

Registering and licensing authority.

(*a*) "Registering authority" and "licensing authority" mean in respect of the United Provinces the Superintendent of Police or in his absence from headquarters, the Assistant or Deputy Superintendent of Police, if authorised by him in this behalf; and in respect of any other part of British India the officer or officers lawfully invested with the powers conferred by these rules on the Superintendent of Police and Assistant or Deputy Superintendent of Police, of licensing and registering respectively;

The Act.

(*b*) "The Act" means the Indian Motor Vehicles Act, 1914;

Motor cycle.

(*c*) "Motor cycle" means a self-propelled vehicle running on not more than three wheels and weighing not more than 5 cwts.

Heavy motor vehicle.

(*d*) "Heavy motor vehicle" means—

(i) a motor vehicle fitted with pneumatic tyres, if it exceeds three tons in weight unladen; and

(ii) a motor vehicle not fitted with pneumatic tyres, if it exceeds two tons in weight unladen.

Trailer.

(*e*) "Trailer" means any vehicle drawn by a heavy motor vehicle;

Motor cab.

(*f*) "Motor cab" means a light motor vehicle which stands or plies for hire in any public place;

Axle weight.

(*g*) "Axle weight" means in relation to an axle of a heavy motor vehicle of a trailer, the aggregate weight transmitted to the surface of the road or other base whereon the heavy motor vehicle or the trailer moves or rests by the several wheels attached to that axle when the heavy motor vehicle or trailer is loaded;

Registered axle weight.

(*h*) "Registered axle wegiht" means in relation to an axle of a heavy motor vehicle, the axle weight of that axle as registered by the licensing authority in pursuance of the rules;

Weight.

(*i*) The expression "weight,." when used in relation to a heavy motor vehicle or a trailer, means—

(i) When the vehicle or trailer is unladen, the weight of the vehicle, including all parts, equipments, stores, fuel, water and accumulators which are necessary for, or are ordinarily used with, the vehicle or trailer when working; provided that, where alternative parts or bodies are used, the heaviest shall be taken for the purpose of calculating the weight; and

(ii) When the vehicle or trailer is laden its weight when unladen, plus its full lawful load, including the weight of the driver;

Width.

(*j*) The expression "width," when used in relation to the tyre of a wheel means the distance measured horizontally and in a straight line across the circumference of the wheel and between the two points in the outer surface of the tyre which are furthest apart;

(k) "Diameter," in relation to a wheel, means the diameter measured between the two opposite points in the outer surface of the tyre which are farthest apart.

Diameter.

III.—GENERAL.

5. Except as provided by rule 40, a motor vehicle shall be driven in accordance with the rules of the road, which require a vehicle to keep on the left of the road, except when passing horses and other vehicles going in the same direction which shall be passed on the right, provided that it shall ordinarily pass a tram car on the left or near side whether it be going in the same or the contrary direction.

Driving on the right side of the road.

6. No person shall, in any public place or street, learn to drive a motor vehicle other than a motor cycle, unless accompanied by a licensed driver.

Person learning to drive.

7. A motor vehicle shall not be driven in a public road or place recklessly or negligently, or at a speed, or in a manner which is likely to endanger human life, or to cause hurt, or injury to any person or animal, or damage to any vehicle or property, or which is otherwise than reasonable and proper, having regard to all the circumstances of the case, including the nature and condition of the road and to the amount of traffic which is actually on it at the time, or which may reasonably be expected to be on it.

Recklessly driving.

8. (1) No motor vehicle shall be driven within municipal or cantonment limits at a greater speed than 15 miles an hour:

Speed limit.

Provided that the speed at which a motor vehicle shall be driven within such limits as the municipal or district board, or the cantonment committee may indicate by means of notice boards within their respective areas shall not exceed such rate as may be shown on the notice board.

(2) The speed at which a heavy motor vehicle, if driven on any public road, shall not exceed 7 miles an hours.

Provided that—

(a) if the weight of the motor vehicle unladen exceeds three tons, or

(b) if the registered axle weight of any axle exceeds six tons, or

(c) if a trailer is attached to the heavy motor vehicle, the speed shall not exceed 5 miles an hour.

Provided also that—

if the heavy motor vehicle has all its wheels fitted with pneumatic tyres or with tyres of a soft or elastic material, the speed at which the heavy motor vehicle may be driven on any public road shall not exceed—

(a) twelve miles an hour, where the registered axle weight of any axle does not exceed six tons;

(b) seven miles an hour where such registered axle weight exceeds six tons.

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IV.—SPECIAL RULES FOR HEAVY MOTOR VEHICLES.

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24. (1) The axle weight of an axle of a heavy motor vehicle shall not exceed the registered axle weight.

Axle weight.

(2) The registered maximum axle weight of any axle of a heavy motor vehicle shall not exceed eleven tons and the axle weight of a trailer shall not exceed seven tons.

(3) The sum of the registered axles weights of all the axles of a heavy motor vehicle shall not exceed sixteen tons.

25. The tyres of each wheel of a heavy motor vehicle or tailer, unless the tyres are pneumatic or made of a soft or elastic material, shall be smooth and shall, where the tyre touches the surface of the road or other base whereon the heavy motor vehicle moves

or rests be flat, provided that the edges of the tyre may be levelled or rounded to the extent in the case of each edge of not more than half an inch.

Provided also that--

(i) if the tyre is constructed of separate plates, the plates may be separated by parallel spaces which shall be disposed throughout the outer surface of the tyre, so that nowhere shall the aggregate extent of the space or spaces in the course of a straight line drawn horizontally accross the circumference of the wheel exceed one-eighth part of the width of the tyre;

(ii) the ~~driving wheels~~ of a heavy motor vehicle shall be cylindrical and smooth-soled ~~or shod~~ with diagonal cross-bars of not less than 3 inches in width, nor more than three-quarters of an inch in thickness extending the full breadth of the tyre, and the space intervening between each such cross-bar shall not exceed 3 inches.

Width of tyres

26. (1) The width of the tyre of each wheel of a heavy motor vehicle or trailer shall be determined by such of the following conditions as may apply to the circumstances of the case:—

(a) The width shall in every case be not less than 5 inches, or, in the case of a trailer, 3 inches.

(b) The width shall not be less than that number of half inches which is equal to the number of units of registered axle weight of the axle to which the wheel is attached.

The unit of registered axle weight shall vary according to the diameter of the wheel, and the rules set forth in the subjoined scale, that is to say—

(i) if the wheel is 3 feet in diameter, the unit of registered axle weight shall be 7½ cwts.

(ii) if the wheel exceeds 3 feet in diameter, the unit of registered axle weight shall be 7* cwts. with an addition of weight in the proportion of 1 cwt. for every 12 inches by which the diameter is increased beyond 3 feet, and in the same propotion for any increase which is greater or less than 12 inches; and,

(iii) if the wheel is less than 3 feet in diameter, the unit of registered axle weight shall be 7½ cwts., with a deduction of weight in the proportion of 1 cwt. for every 6 inches by which the diameter is reduced below 3 feet; and in the same proportion for any reduction which is greater or less than 6 inches.

(2) This rule shall not apply to any tyre which is pneumatic or which is made of a soft or elastic material, or to trailers not exceeding one ton in weight unladen.

Size of wheels.

27. The diameter of a wheel of a heavy motor vehicle or tailer, if the wheel is fitted with a tyre which is not pneumatic or is not made of a soft or elastic material, shall be not less than 2 feet.

Width and length of vehicle.

28. A heavy motor vehicle and any trailer attached to any such heavy motor vehicle may, when measured between its extreme projecting points, be of a width not exceeding 8 feet 6 inches, and no heavy motor vehicle or train made up of a motor vehicle with one or more trailers attached to it shall be used on any street or road if such motor vehicle or train exceeds 75 feet in length.

Springs.

29. Every heavy motor vehicle and trailer shall be constructed with suitable and sufficient springs between each axle and the frame of the heavy motor vehicle.

30. (1) Each trailer attached to a heavy motor vehicle shall have a brake approved by the licensing authority, and each trailer shall carry upon it a person competent to apply the brake efficiently. Provided that where the brakes upon the motor vehicle to which any trailer is attached are so construçted and arranged that neither of them can be used

* Evidently a clerical error for 7½ cwts.

without bringing into action simultaneously the brake attached to the trailer, or if the brake of the trailer can be applied from the motor vehicle independently of the brakes of the latter, the above conditions need not be complied with.

(2) No heavy motor vehicle used on any street or road shall have attached to it more than three trailers.

31. A trailer shall not be attached to a public conveyance, except under a permit granted by the Government or by an officer authorized by it in this behalf.

Vehicles for the conveyance of passengers.

32. (1) Where the registering authority or the District Magistrate, or the Executive Engineer, or a Local Board or Municipality, or Cantonment authority or Railway Administration, affixes or sets up in suitable and conspicuous positions, on each approach to a bridge forming part of a highway, notices which state that the bridge is insufficient to carry a heavy motor vehicle, the registered axle weight of which exceeds that specified on the said notice board, the owner of any such heavy motor vehicle shall not cause or suffer the motor vehicle to be driven, and the person driving or in charge of the motor vehicle shall not drive the motor vehicle upon the bridge.

Use of motor vehicles on bridges.

(2) The owner of a heavy motor vehicle shall not cause or suffer the motor vehicle to be driven and the person driving or in charge of the heavy motor vehicle shall not drive the motor vehicle upon a bridge forming part of a highway at any time when another heavy motor vehicle or a locomotive is on the bridge, the combined weights of which would exceed the carrying capacity of the bridge.

* * * * * * * * *

V.—HILL ROADS AND HILL STATIONS.

37. The following rules shall be in force on the hill roads specified in schedule E which shall be revised from time to time as the Government may prescribe. On all such roads motorists shall proceed with special caution.

38. In the following rules—

"Night" means the period from half an hour after sunset to half an hour before sunrise. The "outside" of the road on a hill means the side from which the slope of the hill is downwards.

A "hill road" means a road constructed on a gradient on the side of a mountain or hill. The District Magistrate shall notify by means of large notice boards on the road-side where each hill begins and ends.

39. No motor vehicle shall travel by night on any of the hill roads specified in schedule E or on any other hill road on which, with the previous sanction of the Government, the District Magistrate has prohibited night travelling by notification in the *Government Gazette*, and by erecting notice boards at the top or bottom of the hill.

Exception—Should a motor vehicle break down on any road on which night travelling is prohibited, the driver, if unable to accomplish the journey before nightfall, may proceed, after executing the necessary repairs, but shall halt at the first police station or police outpost he comes to after dark and there gives his name and the number of his car and a statement of the reasons why he is travelling at that hour, and shall drive with great caution.

40. Motor vehicles shall where practicable, pass all animals or vehicles drawn by animals on the side away from the hill, in whichever direction such animals may be proceeding. Motor vehicles meeting or passing other motor vehicles shall observe the ordinary rule of the road as defined in rule 5.

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VI.—Forms.

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44. All notice boards posted at the sides of the roads under these rules shall be painted red with the notice inscribed in white letters sufficiently large to be easily legible by persons using the roads, and all danger signposts erected by any local authority shall show the signs indicated in schedule F in white on red ground.

45. Such notice boards or signposts shall be affixed or set up perpendicularly to the road and about 275 yards from the obstructions they are meant to indicate, unless the character of their surroundings renders this impracticable, special arrangements being made when the distance of a notice board from its obstruction is considerably more or less than 275 yards. Such notice boards shall be placed on that side of the road which is at the left hand of a person approaching the obstruction.

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Schedule E.

(*See rule* 37).

(1) Kotdwara-Lansdowne Road, between Kotdwara and Lansdowne.
(2) Kathgodam-Naini Tal Roads, between Kathgodam and Naini Tal.
(3) Naini Tal-Brewery-Ranikhet Road, between the Brewery and Ranikhet.
(4) Almora-Ranikhet Road, between Almora and Ranikhet.
(5) Almora-Baijnath Road, between Hawalbagh and Baijnath.
(6) Kalsi-Chakrata section of the Saharanpur-Chakrata Road.
(7) The Mohand and Timli passes.

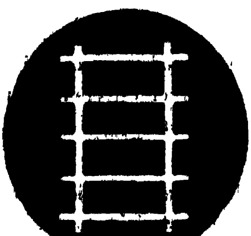
Schedule F.

(*See rule 44*).

Signs denoting obstructions.

ROAD UP.

TURNING.



LEVEL CROSSING

CROSS ROADS

APPENDIX 5.

FIRST INTERNATIONAL ROAD CONGRESS, PARIS, 1908.

FIRST QUESTION.—The Present Road.

1. The Congress draws attention to the necessity for constructing the road foundation very carefully with the toughest material; this constituent of the road plays an important part as exerting a considerable influence on the wear and tear of the highway as well as on the upkeep of its profile While choosing the foundation system, the nature of the sub-soil and the structure of the road as well as the character of traffic using the road are to be taken into account.

2. The Congress is of the opinion that a foundation upon a 4—6-inch concrete course is especially to be recommended in carrying out paving even with large paving stones. In this case the stones are to be laid upon a thin sand cushion.

3. The Congress thinks that it is desirable to continue and to extend the trials made to incorporate tar or bituminous products into the material of the surface with a view to arrive at some efficient and cheap methods of carrying on the work.

4. The Congress recommends that a binder suited to the nature of the road material, and reduced to a minimum should be used while the roller is pressing down the surface.

5. The Congress expresses the desire that the arrangement of the rows of paving stones, either obliquely or perpendicularly to the axis of the road, be noticed and considered. ?

6. The Congress expresses the desire that the paving with small stones (Kleinpflaster) having been reported as giving excellent roads, as regards toughness and cheapness be tested and considered on roads subjected to various forms of traffic.

SECOND QUESTION.—General methods of maintenance.

The Congress considers it advisable to keep as closely as possible to the following indications:—

1. *Macadam Roadways.*

(*a*) Until the experiments in process lead to a complete change in the present methods of maintaining macadam roads, it is recommended that the various services concerned with this maintenance should generalise the complete re-surfacing method and limit the partial repairs to the filling up of important holes, principally at the close of the re-surfacing period, and, above all, during the winter preceding the re-surfacing by means of rollers.

(*b*) Use as far as possible only hard and homogeneous road materials regularly broken; make choice of a binder suitable to the structure of the road materials used, reducing, moreover, this binder to a minimum.

(*c*) Re-surface at once the whole width of the roadway wherever it is possible to turn the traffic out of the roadway upon the sideways or adjoining roads warning boards being placed at the forks in either direction intimating the carrying out of the re-surfacing as well as the road to use for the purpose of avoiding the portion being re-surfaced.

(*d*) Continue and undertake with any development which may appear useful the experiments made with surfaces of materials tarred according to various processes, or with the use of any kind of binding material. It would be necessary to carefully check the results obtained as regards the cost incurred,

sections of length and cross-sections, durability, mud and dust nuisance, intensity of traffic and tonnage in order to determine the type of roadway which best meets modern demands and requirements on roads subjected to the heaviest traffic.

2. *Paved Roads.*

(*a*) Use only materials which are entirely homogeneous and perfectly sorted and selected.

(*b*) Use only clean sharp sand.

(*c*) Keep continually a regular profile by filling up at once any holes and depressions and making the necessary repairs.

(*d*) Undertake a general renewal of paving containing bad faults on the surface over a considerable area, when these cannot efficiently be met by ordinary repairs, which too often introduce other irregularities into the profile.

(*e*) Grant authority to lay water and gas mains, under paved roads, only in exceptional cases and for want of any other practical solution.

THIRD QUESTION.—The struggle against wear and dust.

1. The Congress recommends the use of suitable paving or other improved surfaces as a remedy for wear and tear, as well as dust upon roads subjected to traffic heavy in character or in weight.

2. The Congress recommends the development of cleansing as well as light and frequent watering by mechanical means. The use of surfacing such as will facilitate sweeping and removing of mud is also advised.

3. The Congress considers that emulsions of tar or oils, hygroscopic salts, etc., are really efficient, but unfortunately only for a short time. Their use, therefore, has had to be limited so far to special circumstances (such as motor races, festivals, etc.). It is, however, advisable that trials should be continued both with the substances known to-day and with any similar products that may subsequently be suggested. The planting of trees along the roads is also worthy of encouragement from the point of view of the suppression of dust.

4. (*a*) *Concerning the use of tar.*—The Congress considers that tarring, when well carried out, is undoubtedly an efficient remedy against dust, and that it also to some extent protects the roads against the destructive action of vehicles in general and fast motor cars in particular.

(*b*) *Use of tar incorporated in the road material.*—Experiments up to the present date are not sufficient to allow definite judgment to be passed upon the results obtained. It is desirable that these experiments should be continued bearing in mind the experience acquired in different countries.

FOURTH QUESTION.—The future road.

1. The Congress considers that where the traffic of self-propelled vehicles is not very great, the present road, if it is constructed and maintained in accordance with the resolutions passed on the two first questions, is satisfactory.

2. (*a*) The carriageway of the road of the future should be homogeneous and composed of materials which are hard, tough, capable of resistance and not slippery.

(*b*) There should be but one roadway for every kind of vehicle proportioned to the intensity of the traffic, 19 feet 8 inches (six metres) wide at least, save in the exceptional case of broad pleasure avenues where several separate roadways are to be recommended.

(*c*) Have the least camber compatible with an easy running off rain water.

(*d*) Have moderate gradients with a small difference as possible between the maximum and minimum, it being understood that in exceptional cases, gradients may be sacrificed, if necessary, to avoid sharp curves.

(e) The radii of curves should be as great as possible, 164 feet (fifty metres) at least, the curves being connected with the tangents by parabolic arcs.

(f) The outside of curves should be slightly raised, but so as not to inconvenience ordinary vehicles: no obstruction to the view should be allowed at the curves. A narrow sidewalk bounded by a kerb should be laid on the side of the shorter radius, and the depositing of heaps of materials should be forbidden.

(g) Intersections of roads should be visible and well opened out.

(h) Railway level crossings should be avoided as far as possible, and in all cases should be well opened out and signalled both night and day. Tramway crossings of roads should also be signalled.

3. The Congress recommends that wherever they may be needed tracks for cyclists and paths for horsemen be laid along the roads. Finally, it is desirable that the sides of roads should be clearly defined as much as possible by trees.

FIFTH QUESTION.—Effects of the means of locomotion upon the roads.

A.—Concerning speed.

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1. The traffic of fast motor cars with pneumatic tires causes the disintegration and distribution of the smaller particles of road material. The greater the speed the more this condition is accentuated; the more so if the road is of badly constructed macadam, where the materials are inefficiently bound together and the binding not well incorporated with the road materials. Such circumstances generally conduce to the formation of dust.

2. Too sudden an increase in the speed, as well as too sharp an application of the brakes, considerably increases the damage done to the road surface. All changes of speed also do harm, but in less degree.

3. In the curves the action of the centrifugal force is added to the ordinary effects of speed, and may considerably increase the damage to the road.

B.—Concerning elastic or rigid tires with or without non-skidding devices.

1. With fast motor cars, it is important to reduce as much as possible the damage done to the road by pneumatic tires by using covers formed exclusively of pliable materials, or at most studded with rivets, the projection of which is small compared to their diameter.

2 With heavy motor cars, lorries or traction engines, the tires of the wheels, if rigid, should be smooth, except in special cases and on certain roads.

C.—Concerning the action of weight.

The traffic of heavy motor cars upon macadam roads has a tendency to damage the same, principally by causing depressions and ruts. To avoid this damage, it is important in particular that the pressure per running inch of tire should be moderate in relation to the resistance of the road to shearing action. A maximum of 840 lbs. per inch-width of tire seems generally suitable with diameters of wheels used at present. On the other hand, the absolute axle load is to be considered, as too broad tires cannot exert uniform pressure upon the ground by reason, in particular of the camber of the road. The maximum value of axle load compatible with a sufficient life of the road depends, moreover, both upon the constitution of the latter and the speed of the vehicles.

SIXTH QUESTION.—Effect of roads on vehicles.

The Congress notices that the same conclusion is always arrived at from all points of view, viz., "When the condition of any road is unfavourable to automobile traffic, for whatever reason, the road itself is injured." Therefore if everything is removed from the

road which may cause the vehicles to be injured, the latter are no longer an agent of unusual wear and tear of roads, provided that they are kept within limits compatible with the structure of the road, considered as regards their speed, the constitution of their tires, their accelerations and their weight.

SEVENTH QUESTION.—Road signs.

The Congress expresses the desire—

That the system of marking distances may be reorganised as soon as possible according to a general and uniform plan for the whole territory of every country.

That the principle of this organisation may be the connection of large centres.

That the indications of distance may begin from the large towns as regards all roads radiating from them.

That a uniform model for all milestones may be used, and that the inscriptions may be few in number and very legible.

That a uniform method for calculating the distances may be adopted to facilitate the calculation of cumulative distances.

That steps may be taken to obtain from the several countries the application of identical principles.

That the administrative indications may be limited as much as possible on the boards indicating the directions in order to obtain a large surface for the inscriptions of direction.

That, from the point of view of the interests of international traffic, a system of warning signals representing the kind of danger and including its name in the national language should be adopted in all countries.

That the number of signals should be limited to four : (1) Obstruction across the road, (2) corner, (3) level crossing, and (4) dangerous cross roads.

That danger signals, when they are supplied by private bodies, provided that they are approved by the authorities and placed in position by them or under their inspection, should be considered as belonging to the highway, and should have the protection of the existing law relating thereto.

EIGHTH QUESTION.—The road and services of mechanical transport.

(1) Automobile vehicles may be advantageously used for public conveyance without injuring the road to any noticeable extent, upon the condition that the average speed does not exceed 18 km. and the maximum speed does not exceed 25 km. ; the weight of the driving axle must also be reduced to a strict minimum, and the weight of the heaviest axle must not exceed 4 tons when working. The pressure on each centimetre of the width of the wheel rim must not exceed 150 kgs. for the wheels of the diameter at present in use.

(2) Transports for industrial purposes by means of explosion motor lorries may cause no injury to the road, upon the condition of observing the following limits as regards speed and weight :—

For the average speed of 10 km. and maximum speed of 15 km. the weight of the heaviest axle, when working, must not exceed 5 tons ; the driving axle may have metallic tires provided that these have smooth faces.

In all cases the pressure of the tires per centimetre of the width of tire must not exceed 150 kgs. for wheels of existing dimensions.

(3) It is difficult in the present condition of the roads and of the automobile industry to answer the questions arising from the traffic of heavy steam lorries, and traction engines as their use is necessarily limited to a comparatively small extent ; it would be useful in case of need, to fix definite routes on existing roadways.

(4) In order to affirm these data and make them more complete, the Congress considers it desirable to collect exact particulars compiled by competent authorities, as to determine the relations to be kept between the constitution of the roadways and the power of resistance of structures connected therewith, and the speed, weight, width of tires, diameter of wheels and nature of the tires of the vehicles, the method of suspension of vehicles, the number of axles and their distance apart.

(5) For the maintenance of the road, as well as for its good working, it is desirable to lay the tracks of light railways outside the bed of the road; at any rate, it is advisable to lay the tracks of these railways and of the tramway lines on special beds, leaving the road a minimum width of 5 metres clear of the railway.

(6) When tracks must be laid in the roadway, it is desirable that they should be laid at the level of the surface without any projection or depression, and without any change of contour, either in the transversal or in the longitudinal direction, and that the roadway should be such that a width of at least 2 m. 60 should be provided clear of the portion of the surface on which tram cars will run; it is recommended that the rail should be provided with a counter-rail, which be either connected to the rail and form a unique hollow rail, or be separate.

(7) The Congress expresses the desire that tramway authorities may continue in the general interest the researches already carried out with some success in order to improve the construction and maintenance of the tracks, and especially of the plant laid in the roadway, and that they will remove everything which may impede general traffic.

SECOND INTERNATIONAL ROAD CONGRESS, BRUSSELS, 1910.

FIRST QUESTION.—Metalled and paved roads.

(Use of binding materials in the construction of metalled roads. Use of trackways in the paved roads. Progress made in combating wear and tear and dust).

I.—Use of binding materials in the construction metalled roads.

The Congress believes that it is desirable to persue and develop the applications of the use of binding materials in the construction of metalled roadways, special attention being given—

1. To determine, in each case, the character of the binder best suited to local conditions.

2. To determine, as exactly as possible, the physical and chemical characteristics to be specified for tar, bituminous, asphaltic or other binders as best suited.

3. To compare the different results obtained in various methods of construction.

4. To investigate the influence that storing of tarred metal, during a more or less extended period before being used, may have upon the perfection of the work.

5. To make a study of the deterioration that the materials are subjected to during use.

6. To specify the system to be advised, where ordinary metalling has proved deficient and stone paving cannot for some reason be applied.

7. To establish for each district according to local conditions, and in each case, the relation between cost and the result obtained.

II.—Use of trackways in paved roads.

(a) Apart from exceptional cases depending upon local conditions, the construction of trackways in paved roadways can but be considered an expedient.

III.—Progress made in combating wear and dust.

Confirming the resolution passed at the Paris Congress in 1908, and under re-collection of the above in further reference to the first resolution just adopted and which is of interest not only

from the point of view of combating wear and dust, but from that of binding materials in metalled roads, the Congress believes—

1. That superficial tarring may be considered as definitely accepted in practice, and that the advantage to be derived from spreading fine sand or suitable stony material after tarring and rolling the same is not at present proved and should form the object of comparative tests.

2. That in the future applications of these methods, the attention of road builders be drawn with benefit to the comparison of results obtained by the laying of tar, bituminous or asphaltic substances, hot or cold, by machine or by hand, both from the point of view of cost as from the point of view of the efficiency of the operation.

3. That it is desirable, in comparing results, to take into account the quality of the materials composing the metalling, the intensity of traffic and tonnage as well as the climate.

4. That, with due regard to the resources of each region in tar, bituminous or asphaltic substances, it is important to specify in contracts the conditions that are to be fulfilled, specially as regards the preservation of "life," that is to say, the property of preserving their binding power.

5. That it would be desirable that a comparison be established between the advantages of tarring—this word being taken in its broadest sense in different cases; whether the operations are to be frequently repeated, small doses being applied each time; or whether large quanties are to be applied at greater intervals. Furthermore, whether, in the metalling itself, a tar bituminous or asphaltic binding material, has already been incorporated or not.

6. That the conclusion adopted by the first Congress is to be maintained *in toto* running as follows: emulsions of tar or of oil, hygroscopic salts, etc., . . have a real, but not a lasting efficieny. Therefore, their use should be limited to special circumstances, such as race-courses, festivals, processions, etc.

SECOND QUESTION.—Foundation and drainage of roads. (Method of carrying out the work).

Foundation.

I. The formation and construction of foundations of roadways should be made the stronger in proportion to the lesser compactness of the ground. The foundation should have more body and resistance the more it is exposed to internal deterioration and external wear.

II. In the choice of the system of foundation for roadways, both stone set and metalled, stress should be principally laid on the degree of dryness and dampness of the sub-soils, while having regard to the possibility of their drainage and to their geological nature and to the nature of the materials of the locality. In order to determine the thickness and the extent of the massive of the foundations, pressure for unit area should be made compatible with the carrying resistance of the soils observed under the most unfavourable conditions.

Drainage.

III. In soils, where preliminary drainage is required before the construction, the general methods of drainage should be applied to the whole or to a part of the road body and to the bed of the metal, if necessary.

IV. The cross and longitudinal sections of roads and those of side gutters should be established so as to facilitate the flow of the trickling water and to prevent infiltration of water into road surfaces, which should be made as impermeable as possible. The evaporation of superficial dampness should be encouraged by every means.

V. The works for the foundation and for drainage should be carried out simply and economically and by using of the materials of the country as far as possible.

THIRD QUESTION.—Laying light railways and tramways on roads. Advantages and disadvantages. Effect on the various methods and the cost of maintenance.

I. In the study of the new roads to be constructed, both in the neighbourhood of large towns as well as in the open country, it may be useful to try, if it does not interfere with the general interest, to provide a sufficient road width for the construction of a light railway outside of the roadway.

The trace, the gradients, the designs of cross-section will be, according to the requirements, determined in such a manner as to reserve all the facilities and necessary safety for every kind of traffic.

It is desirable that the supplementary costs should be defrayed by the concession-holder or the constructors of the light railway as far as the part of road reserved for the rail track is concerned.

II. The construction of sunken rails in the metalled roadways are always harmful for the viability of the roads, and there results a marked increase in cost of the maintenance of the roads. It is desirable that this method should be avoided as much as possible.

The establishment of rails for tramways in paved roads makes the repair of the paving very difficult, where abutting against the rails. It is necessary to diminish that nuisance, as far as possible, by appropriate methods.

III. Where the railway is placed by the side of the road, it is preferable, where the width of the road permits, to construct it on a special track, inaccessible for wheel traffic and super-elevated in order to allow greater safety.

It is necessary in all cases to provide proper drainage.

If it is a case of metalled roadways, the concessionary or constructor of the railway should be obliged to construct on the outside border of the free roadside sufficient depôts for materials for the repair of the road. The same obligation should be, in some cases, extended to paved roads.

IV. The removal of trees along the roadsides should not be tolerated, unless in extraordinary cases.

If the width between the tree rows is insufficient for the rail track to maintain the recognised necessary width for ordinary wheel traffic, the track should be laid on the outside of the trees.

V. It is desirable that the concessionary of light railways should undertake the duty of maintaining the area of the road or roadway occupied by the rails or contiguous to same, or pay the costs of this maintenance.

FOURTH QUESTION.—Cleansing and watering (Necessity or utility. Methods in use. Their costs. Comparison of various methods).

Throwing refuse upon the public roads should be carefully avoided. Such refuse should be swept and removed by the municipality and not by the owners of adjoining property, provided the cost of this work is recovered from the latter by taxation.

In large towns it is necessary to give special care to cleansing and watering.

Cleansing should be done as rapidly as possible.

Watering must be frequent and limited in amount depending on local conditions.

Washing and sweeping are to be done as early as possible. Mechanical processes are particularly recommended.

Improvement in the implements are to be sought for with a view of insuring the most complete cleaning with the least inconvenience to the public.

Motor machines are called upon to be advantageously used for the cleaning and road watering in large towns.

FIFTH QUESTION.—Choice of surfacing materials.

1. Macadam carried out according to the methods of Tresaguet and Mac-Adam, causes dust and mud, is expensive to maintain, and is suitable in large cities only for streets where the traffic is not very great or heavy.

2. The experimental work carried out in recent years with macadam improved by using bituminous or tarry-coating or binder must be continued in order to determine the best methods of utilizing this kind of construction under varying conditions, so that this question may be submitted again at the forthcoming Congress.

3. Stone pavement has great qualities of resistance and durability. Its maintenance is easy and economical; it produces hardly any dust and is suitable where there are tramway tracks.

4. It should be adopted in thoroughfares wherever noise is of little consequence, or when asphalt surfaces are not suitable. It should consist of sets regular in shape, durable, but not slippery, wearing evenly, laid upon a foundation and with close joints.

5. The Congress expresses the wish to see the trials of small set pavements continued wherever local circumstances and traffic conditions permit.

6. Wood paving is noiseless, not slippery, if kept clean; it stands very heavy traffic. The use of it should be extended even to thoroughfares through which tramway lines run.

7. The respective advantages of soft and hard wood blocks must be a subject of discussion at a forthcoming Congress.

8. Asphalt pavements should be recommended owing to their good qualities from the hygienic point of view, their ease of cleansing and of repair, and owing to the small traction effort required on them. This surfacing is almost noiseless and produces but little dust, but it is unsatisfactory adjacent to tramway rails.

9 There is opportunity for its use in fashionable thoroughfares where the traffic is not severe, where there are no tramways, and where the gradients are very moderate.

10. Finally the trials of asphalt, flag and block pavements, regarding those qualities not yet determined, should be continued.

SIXTH QUESTION.—Methods of carrying out road work in connection with lighting and water-supply.

1. It is desirable to free as far as possible the carriageways from the minor distribution systems which now encumber them and to leave in them only the large sewers and mains which require little attention.

2. As far as possible the minor distribution mains which are connected to the adjoining houses should be doubled and placed on both sides of the street. This doubling is especially recommended for streets with heavy traffic and also for those where the surface rests on a solid foundation.

3. It is advisable to consider the advantages of placing all distribution systems, except gas, in sub-ways of suitable dimensions placed under the footways. In this case great care must be taken to prevent flooding caused by breakage of water pipes.

4. When the distribution works have been actually placed under the carriageway, the Congress advises that the system of doubling should be applied prudently by taking advantage of the opportunity given by considerable repairs or alterations.

5. Complete agreement is necessary between all authorities interested in streets, in order to conduct their operations so as to interfere as little as possible with the traffic. It is most desirable that all street works should be under the general direction of those responsible for maintaining the surface.

The work must be carried out as rapidly as possible and so as to reduce the space occupied on the public highway and obstruction to traffic.

6. Trees planted in the footways in urban districts should be chosen so as not to inconvenience the frontages by their leaves, nor to interfere by their roots with the distribution systems.

SEVENTH QUESTION.—Influence of weight and speed of vehicles on bridges and other special structures.

1. The development of mechanical traffic has not had, up to the present, the effect of increasing the weight of vehicles generally beyond the limits recognised by regulations and custom in connection with constructional calculations.

In any case it is desirable that, when existing regulations are revised, steps should be taken to test bridges by placing upon them the heaviest probable loads under the most unfavourable conditions and exclusively composed of mechanical vehicles.

2. Under the present conditions of constructing motor vehicles and building public roads, it does not seem possible that the speed of vehicles could have any effect on modern and well-built bridges which have not already been duly taken into account in the usually adopted methods of calculations of strength.

It may be advisable, however, when testing new bridges or re-testing existing bridges, to make use of the heaviest motor driven vehicles permitted to run, and running them at high speed.

3. The consolidation (solidarisation) of the different parts of which bridges are composed, aid their capacity to withstand the effects of vehicular traffic.

EIGHTH QUESTION.—Road vehicles. (Conditions to be fulfilled by horse or mechanically driven vehicles in order that they may neither cause nor suffer any extraordinary damage to or from the roads).

A.—With regard to animals drawn vehicles.

1. Heavily loaded vehicles with narrow tyres may cause exceptional damage to roads laid down with a view to general traffic.

2. It is desirable that trials be taken in hand for the purpose of determining the relation which should subsist between the load, the diameter of wheel, and the width of tread so as to avoid abnormal damage.

B.—With regard to mechanically drawn vehicles.

1. Such automobiles as fall under the head of "touring cars" cannot cause abnormal damage to the roads so long as their speed is kept within limits.

2. Public service automobiles cannot cause appreciable damage to the road, provided the maximum speed does not exceed 25 kilom. per hour, the maximum axle load does not reach 4 tons on the heaviest loaded axle, and that with wheels of 1 metre diameter, the load is below 150 kg. per centimetre width of tread.

3. Industrial automobiles need not cause exceptional damage to a well-constructed road, provided that the following limits are adhered to:—

1st type—Vehicles in which the axle load is less than 4½ tons—

Maximum speed, 20 kilom. per hour.

Load on tyres; 130 kilog. per cm. of width of tread with wheels of 1 metre in diameter.

In narrow streets in towns and in large cities when vibrations of the ground are to be feared, it is possible to minimise the inconvenience by reducing the speed in a suitable proportion.

2nd type—Vehicles in which the maximum axle loads between $4\frac{1}{2}$ and 7 tons—

Maximum speed, 12 kilom. per hour.

Load on tyres: 150 kilog. per cm of width of tread with wheels of 1 metre in diameter.

Provisionally and under reserve of the results of further experiments when the diameter of wheels is above 1 metre, the load per cm. width of tread should be calculated for both types of vehicles and also for such as are described in paragraph 2 by using the formula—

$$C = 150\sqrt{d}$$

where d = diameter in metres and C = the load in kilograms.

It is desirable that experiments should be undertaken in order to determine the maximum width which can be given to the tyres of all automobiles while still insuring that, under normal conditions, the distribution of the load on the ground should take place over the whole carrying area.

4. Ribbed or grooved iron tyres cause abnormal damage to the road, no matter what their width be, or what load they support.

5. Vehicles propelled by mechanical power cannot cause extraordinary damage to the curved portions of roads, provided that at these points a sufficient superelevation is given and that the curved portion is not approached or traversed at an unreasonable speed.

6. With a view to saving the roads, it is desirable that the car builders go carefully into the question of clutches and brakes so that the skidding of the wheels may be avoided; that they also balance the motors as perfectly as possible, and that they allow a reasonable raising of the centre of gravity.

NINTH QUESTION.—Conditions for the use of public service conveyances other than tramways. (Advantages and disadvantages, capacity, costs, etc.).

The Congress is of opinion that public motor omnibus service should be encouraged.

As a final resolution, the Congress is of opinion that it is difficult at the present moment to decide definitely on the respective advantage of the two modes of transport, but that one forms the complement of the other and not the rival, and the adoption of one or other method largely depends on local conditions.

The progress of motor omnibus and extent of the use of this method of transportation is capable of great extension:—

(*a*) by the use of wheels fitted with rubber tyres,

(*b*) by any progress made in construction.

The number of passengers carried by motor omnibuses should be greater for the town than for the country.

THIRD INTERNATIONAL ROAD CONGRESS, LONDON, 1913.

FIRST QUESTION.—Planning of new streets and roads.

1. As a general principle, it is better that new main roads be constructed to pass outside, rather than through towns, and that, where an existing main road passing through a town is unsatisfactory for through traffic, it is often better in preference to widening an existing narrow main road through the centre of a town. New roads should be planned according to the principles of the science of town-planning.

2. Gradients on new roads should be as easy as possible, having regard to the physical character of the country through which they pass, and they should be easier where there are curves, trams or a preponderance of heavy traffic.

3. The radii of curves in roads used by fast traffic should, where practicable, provide the best possible and an unobstructed view, and that where this is not possible, the curve being of short radius, means should be provided whereby the approach thereto is in some way clearly indicated.

4. Except where it is possible to provide special reserved spaces, tram tracks are best placed in the centre of the roads, and that when so placed, it is desirable to provide space on either side for two tracks for vehicles.

5. The main traffic roads should be so designed that spaces are provided for tram tracks, fast and slow traffic and standing vehicles, and in such a way that they can proceed without unduly intermixing. In fixing building lines along what may ultimately become main roads, regard should be paid to ultimate requirements. Adequate space should be provided between buildings, and powers for enforcing this should be held by all authorities who decide the widths of roads.

6. That the planning of main road communications outside towns should be at once undertaken; it is a matter of national importance in regard to which some initiative should rest with a central State authority, and the action of local authorities should, to some extent, be regulated or supervised by central authorities.

SECOND QUESTION.—Types of surfacing to be adopted on bridges, viaducts, etc.

1. The choice of road surfacing for bridges depends on the nature and intensity of the traffic, the local conditions, such as permissible first cost, kinds of material readily available, and climate. For light bridges the choice is largely influenced by the weight of the surfacing Public safety and convenience should be first regarded rather than questions of comparative cost.

2. On short bridges in town or country, it is desirable that the surfacing should be the same as that on the adjoining streets or roads.

3. In forming the roadway on bridges, special care should be taken to secure proper drainage and to prevent the harmful percolation of water with longitudinal gradients of at least 1 in 50, the cross-section of the surface made be made nearly flat and the dead load thus reduced.

4. As a general rule, the surfacing of a bridge should be water-proof, capable of resistance to wear, durable and of a weight appropriate to the structure of the bridge: it should also be as smooth as possible without being slippery.

5. Plank surfacing on bridges is light, and its first cost is low. Its cost of maintenance is, however, excessive, except where the traffic is light. Its extreme liability to damage by fire is a serious disadvantage. It should not be adopted, except in remote districts in which there is an abundance of cheap timber, and where a more desirable form of surfacing is not easily obtainable. Single plank floors are only suitable for very light traffic. For moderate or heavy traffic, two layers of planking, the lower of which is creosoted or otherwise protected from decay, should be used.

6. Macadam, or ordinary broken stone surfacing, on timber planking, is not always satisfactory on account of its great weight and its permeability. Macadam is, however, quite satisfactory for massive bridges in rural districts, if the sub-structure has a proper damp-proof course.

7. Macadam bound with tar or other water-proof and elastic material is useful and economical for the surfacing of rural bridges with moderate traffic when the spans are short or the structure is massive.

8. Wood block paving, 3 to 5 inches thick, is an ideal surfacing for bridges in most cases. It is light and durable and can be laid on concrete, or, when weight must be minimised on a timber sub-floor, which should be creosoted. Special care should be taken in the selection, treatment, and laying of wood blocks for bridge paving to avoid troubles due to expansion and contraction of the blocks or of the metal structure.

9. Asphalt in various forms is an excellent surfacing material for bridges with easy gradients on which the traffic is not confined to definite lines or very heavy.

10. Stone paving, carried out with ordinary hand-dressed setts or with small setts (Durax, Kleinpflaster) laid on concrete and bound with cement or pitch, makes excellent and economical surfacing for bridges with heavy traffic. However, it is only suitable in cases where questions of weight of the surfacing or of noise are of no importance. The thickness of the layer of sand interposed between the setts and the foundation will be decided in the same way as with an ordinary carriageway in town or country, as the case may be.

11. For movable bridges and for non-rigid suspension bridges, the surfacing should be light and easy to attach to the bridge platform. The trials made in France and Belgium with old mine cables or other fibrous substances of even less cost, and with such materials impregnated with tarry, bituminous, or asphaltic materials, should be encouraged.

THIRD QUESTION.—Construction of macadamised roads bound with tarry, bituminous, or asphaltic materials.

By the use of bituminous, including tarry or asphaltic binders, we may obtain a number of different forms of road crust, which may be employed with advantage, according to the various conditions of the road as regards traffic, locality, and climate.

The exact value and duration of life of these various road crusts, taking into account traffic, climatic conditions and the methods of construction, remain to be determined.

For this purpose it is advisable to draw up a uniform system of tests, measurements, and records under the following headings :—

1. Physical and local conditions. (Plans, cross-sections, slopes, camber, foundations, sub-soil).

2. Materials employed, petrological analysis, dimensions, compositions of the binding agent.

2*a*. Method of construction, date of construction.

3. Census of traffic on the section under review.

4. Climatic conditions affecting the road.

5. Periodical measurement of wear.

6. Periodical examination of the state of the road crust.

7. Actual cost of the road crust (*a*) as regards cost of construction, (*b*) as regards maintenance cost.

The standard form in which the information is to be furnished will be drawn up by the Permanent Commission.

PARTICULAR CONCLUSIONS.

I.—Foundation and drainage.

Confirming the conclusions adopted in 1910 by the second Congress (Brussels), Question 2, which called attention to the advantages of a dry foundation and a sound sub-soil, the Congress especially insists upon the great importance of efficient foundations in the case of road crusts bound with bituminous (including tarry or asphaltic) binders for the following reasons :—

1. The road crust being expensive, it is important to give it a base which will increase life.

2. As weight, speed, and intensity of the traffic continually tend to increase on roads considered worthy of such a crust, it is best to provide a foundation which has been so constructed as to secure for the crust the best possible conditions of resistance to wear.

II.—Dimensions and slope of metalling.

1. When an ordinary macadamised road crust is constructed with a view to being tar-sprayed, it should be constructed of hard metal with sharp edges, and broken as nearly as possible to a cube of the dimensions of from 4 to 6 cm.

2. In the case of bituminous, including tarry or asphaltic, macadam, carried out by the mixing process, the dimensions of the metal may be so selected and graded as to form a compact road crust with the fewest possible voids.

The dimensions of the largest metal may vary according to the nature of the stone and of the traffic. When the process of construction employed requires more than one layer of material, the upper layer of wearing crust may be formed of smaller metal.

3. In respect of bituminous, including the tarry or asphaltic road crusts constructed by the penetration process, the trials and tests now being carried out in various countries should be continued, taking care only to employ metal of as cubical a shape as possible, and with sharp edges, at any rate for the portion of the road crust nearest the surface.

4. It is understood that further experiments will also be carried out in the use of other methods, and especially those referred to in paragraphs (1) and (2).

III.—Employment of partially used metal.

By carefully eliminating all particles of mud and organic matter, it is possible to successfully make use of partially worn materials, on condition that they are not employed for the surface of the road crust.

IV.—Relative importance of patching.

It is agreed that it is absolutely necessary to carry out repairs, in the case of all bituminous, including tarry and asphaltic road crusts, immediately the necessity for them arises.

V.—Permissible wear.

The compact renewal rendered necessary by the wear and tear must be carried out immediately the depth of the road crust is below a given limit of safety, or when its water-proofing qualities have become so poor that the road will unduly suffer from climatic conditions.

VI.—Various means of employing tarry, bituminous, and asphaltic materials.

In using these materials both in the penetration method and the mixing method :—

(*a*) It is preferable to use dry stone in order that it may adhere well to the binder. In the mixing method the stone must be dry, and, if necessary, it must be heated.

(*b*) One must never lay a top crust upon a soft or damp foundation. One should preferably carry out the work in fine weather.

(*c*) One must never employ too much binder, but only a sufficient quantity to bind the portion of the road which is being rolled.

(*d*) One must never employ road rollers which are too heavy.

VII.—Tests and chemical analysis.

The advantage of analysis and methodical laboratory tests, and their necessity in the case of bituminous binders, are unanimously recognised.

It would be of advantage to obtain uniformity—

(1) As regards the specification of the principal characteristics of these binders.

(2) As regards the methods of testing for drawing up these specifications. The Permanent International Commission will be entrusted with the work of inquiring into the best way of standardising the above.

VIII.—Climatic effects.

It appears to be generally agreed that certain tarry, bituminous or asphaltic road crusts (as is also usually the case with all smooth and water-proof surfaces) may become slippery

under certain conditions of weather. This may be remedied by strewing the surface with coarse sharp sand; and, in most cases, a good cleansing of the surface will usually prevent the carriageway becoming slippery.

IX.—Effects on public health, etc.

Sufficient information is now available to enable engineers to select and specify bituminous binders which will have no prejudicial effect upon public health, fish life, or vegetation, but which, on the contrary, will conduce to conditions of considerable hygienic advantage.

X.—Cleansing and watering.

It is recognised that carriageways properly treated with bituminous, including tarry or asphaltic materials, require less sweeping and watering than ordinary water-bound macadamised roads, and that they allow of considerable economy being effected under this head.

The meeting puts forward the following additional proposals:—

That an International Technical Committee should be appointed by the Permanent International Commission, in order to study a standard method of obtaining information and data upon materials, physical conditions, local conditions, methods of construction, terminology, and other points concerning macadam bound with tarry, bituminous or asphaltic binders.

The report of the Committee should, after examination of the Permanent Committee, be presented to the next Congress.

FOURTH QUESTION.—Wood paving.

1. Where gradients permit, wood-block pavement is very suitable for streets where the traffic is great, but is not of the exceptionally heavy character usually existing on streets near docks, or similar centres of industrial traffic. It should be used where a noiseless pavement is desirable. It is of great importance that a concrete foundation should be laid of sufficient strength to carry the traffic passing over the pavement.

2. Great care is necessary in the selection of the proper timber for the purpose, and all soft wood blocks should be thoroughly impregnated with a well-proved preservative before being laid.

3. In view of the varying results given by wood pavements, according, to local circumstances, it is desirable that further investigations and laboratory experiments should be carried out in connection with the selection of the timber and of the impreganting preservative.

4. Every precaution should be taken in laying the blocks to prevent, so far as possible, the entry of water through the joints.

4*a*. Hard woods give varying results according to local circumstances, and it does not appear desirable to recommend them for roads with intense traffic in large cities, unless some means are devised to effectively prevent the rapid destruction of the joints and the resulting destructive effect on the concrete below. If these woods are employed, it is desirable not only to prevent the percolation of water through the joints to the foundation, but also to consolidate the blocks as far as possible so that they may not become rounded at the edges.

Soft wood obtained from suitable kinds of trees, and especially from resinous species are equally suitable for roads with a comparatively heavy and intense traffic as well as for roads with a light and infrequent traffic. In the latter, however, the blocks are liable to rot if they have not been suitably picked. It is also desirable to make the joints as small and water-tight as possible. On the other hand, their comparatively rapid wear on roads

with great traffic should encourage one to make exhaustive investigations into the best means of treating them, so as to increase their strength without prejudice to their elasticity.

5. Subject to certain precautions, such as impregnating of the wood, water-proofing of the joints and surfaces, frequent cleaning of the roadway, etc., there is no objection to wood pavement from the sanitary point of view.

6. The spreading of gritting is necessary under certain conditions and in certain weather (especially hard wood paving) to prevent the surface becoming slippery, but the gritting should be done with suitable small gravel chippings or sharp sand, so as to avoid, as far as possible, any injury to rubber tyres.

FIFTH QUESTION.—Methods of lighting.

I. For the purposes of a general determination of methods of lighting, highways may conveniently be divided into three classes as follows :—

(1) Important streets in cities, towns or other urban areas in which the traffic, after dark is considerable in volume.

(2) Important suburban roads in the vicinity of large towns.

(3) Rural roads in open country ; and having regard to modern conditions of traffic, it is essential that adequate lighting by means of fixed lights should be provided in classes 1 and 2.

II. As a general principle in the lighting of all highways which require to be lighted by means of fixed lights, the method of lighting to be adopted should be such as will provide an illumination as uniform and free from glare as possible. The amount of illumination and the position of lamps must be determined with reference to local circumstances.

III. It would be impracticable to light rural roads in open country generally by similar methods to those adopted in urban streets or suburban roads, and the lighting of vehicles running or standing on rural roads at night is, therefore, of the highest importance.

IV. Every vehicle, whether standing or moving, should carry or show a light of sufficient power at night which can, except when especially authorised, be seen from the rear as well as from the front of the vehicle.

(2) Every motor car must carry, after nightfall, two lighted lamps in front and one at the back ; if it is able to move at a high speed, it must be fitted in front with a head lamp of sufficient illuminating power to light up the road or path for at least 50 yards to the front. In inhabited places the ordinary lighting is sufficient to allow motorists to see their way and be easily seen, the light of the headlights must be limited to that of the ordinary lamp.

V. It is desirable that all obstacles across a road, such as gates, and particularly gates at level crossings, should be painted white and in other colours in alternate parts, and illuminated by fixed lights which are lighted at dusk.

(2) It it desirable to paint white, or indicate by some other method, all danger signal posts, direction posts, and other posts, milestones, wheel kerbs, bridge abutments, etc., or other special features the indication of which would aid travellers or conduce to the safety and convenience of traffic.

VI. One and the same colour should be adopted as the colour for danger signals.

The meeting, on the proposal of Mr. Chaix, unanimously adopted the following resolution:—

"It is desirable that each Government should do away as soon as possible with coloured lights on automobiles."

On the proposal of Mr. Hausez, the meeting adopted the following resolution, with two dissentients :—

"The Congress expresses the wish that regulations should be made to compel drivers of cattle to make their presence known at night."

SIXTH QUESTION.—Observations noted since 1908 as to the various causes of wear and deterioration of roadways.

1. Weather conditions are amongst the most powerful influences which cause deterioration of roads, and that the destructive effect of weather can be minimised by effective water-proofing of the road surface, with suitable drainage for the foundation.

2. Any considerable volume of traffic consisting of either heavy motor vehicles or high-speed light motor cars has a seriously damaging effect on water bound macadam roads.

The damage caused is effected by the balancing of the motor, the ratio between propelling power and adhesive weight, the weight of unsprung portions of the motor, the progressivity of action of the brakes, the system of springing, the type of the tyres employed, the diameter of the wheels, the width of the rims, variation of speed and adherence, and other factors.

3. The damaging effect of heavy motor vehicles can be minimised by the use of wheels of large diameter, tyres of a width properly adapted to the weight of the axle load, rubber or elastic tyres and suitable springs, and that all reasonable means of reducing the damage to roads caused by such vehicles should be enforced.

4. Light motor car traffic does not cause serious or exceptional wear or damage in the case of properly-made macadam roads which have been properly treated or bound with tarry, bituminous or asphaltic materials, except in sharp curves.

As regards horse-drawn vehicles, it is desirable also to study the relations between loads, width of rims and diameter of wheels, and more especially the system of shoeing horses. It is also necessary that powers should be given to local authorities to prevent the deposit of refuse from fields and earth from the roadway by the wheels of agricultural carts.

5. There is still a great lack of precise information in regard to the various causes of wear and deterioration of road ways and that it is desirable to collect more information compiled on carefully devised scientific methods, standardised as far as possible for the purposes of comparison, and to make further systematic study of these causes.

The International Permanent Commison is charged with the preparation of a programme of observations, studies, and experiments.

SEVENTH QUESTION.—Regulations for fast and slow traffic on roads.

1. That all regulations for the control of road traffic should be based on the principle of allowing the speed practicable for each different kind of vehicle consistent with public safety, general convenience, and the normal wear of the road.

2. That regulations for the conduct of fast and slow traffic should be as few and simple as possible, and should be such as can and ought to be universally adhered to and enforced.

3. That in all large cities there should be a traffic authority on whom would be charged the duty of studying and dealing with street traffic problems, and the co-ordination of such powers with those of other public authorities being matters of detail which must be settled by public authorities on consideration of the circumstances and conditions of each large city.

4. That there should be ample provision of traffic controllers (such as the police in London) with adequate powers to regulate the traffic, not only at congested points, but throughout the course of crowded streets.

5. That having regard to the increased danger which is necessarily created by the conditions of modern traffic, it is important that drivers should be carefully and systematically trained, and that children should be especially taught how to provide against the dangers of the road.

6. That except where local circumstances render it absolutely necessary, no obstructions, such as lamp-posts, tramway standards, etc., should be placed in the centre of a road, except necessary refuges for pedestrians crossing.

7. No obstruction of the public highway should be permitted either by vehicles standing unreasonably, or travelling at an obstructing speed, or by things placed on the highway. Exception must, however, be made for depôts required for the work of maintenance or repair of the road, or for work being carried out by duly authorised and competent authorities, but in every case all necessary steps must be taken to ensure the safety of traffic.

8. The meetings, on the proposal of Mr. Chaix, unanimously adopted the following resolution :—

> "Regulations for roads and traffic must aim at defining the rights, duties, and responsibilities for each kind of traffic, in order to avoid the causes of accidents and damage and to ensure the maximum of order and liberty."

EIGHTH QUESTION.—Authorities in charge of the construction and maintenance of roads. Functions of central and local authorities.

1. The system of road administration in any country must be in harmony with the general system of Government prevailing in that country and the political genious of its people. It is impossible to lay down any general rule of universal application as to the extent to which the road organisation of any country should be centralized or decentralized.

2. A principle that can be laid down as of universal application is that the unit of highway administrations shall be sufficiently large and command sufficient resources to employ and adequately remunerate a competent staff.

NINTH QUESTION.—Finance of the construction and upkeep of roads. Provision of revenues.

1. The expenditure of the maintenance and improvement of—

(a) The roads which serve as main routes of communication between important places in any country ; or,

(b) Roads which are used mainly by long distance traffic.

Unless such expenditure is borne wholly out of the National Revenues under a system of State administration of roads (which system is practicable and suitable in the case of some roads in some countries) should be mainly paid out of National Revenues, whether or not such roads are locally administered and maintained, subject, where local administration prevails to the supervision of a central Government Authority both as to efficiency add expenditure.

2. It is desirable to abolish, so far as possible, all tolls on public roads, and it is equitable that vehicles which, on account of their weight, or weight combined with speed, or any other exceptional circumstances connected with either the vehicle or use of the road, cause special damage to roads beyond the wear and tear of the ordinary traffic of any district, should be subject to special taxation, the proceeds of which should be earmarked for expenditure on roads.

3. Borrowing money for new road construction and for the periodic renewal of the surface coating of a road is consistent with sound financial principles, provided the loan period in the case of loans for renewals is kept well within the life of the surface coating.